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VERTEBRAL COLUMN WITH SIX AND A HALF CERVICAL AND THIRTEEN TRUE THORACIC VERTEBRÆ, WITH ASSOCIATED ABNORMALITIES OF THE CERVICAL SPINAL CORD AND NERVES.

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INTRODUCTION.

THE vertebral column and portion of spinal cord described in this paper were obtained from a male subject, aged 61, dissected at Leeds during the Summer Term, 1913. The column is not complete, as it suffered that annoying damage which frequently overtakes interesting abnormalities discovered after dissection has been in progress for some time. The laminæ from the 6th cervical downwards have been sawn through, the spinal cord from the same level destroyed, and the sacrum broken through its lower half. This damage, however, causes no serious difficulty, as the main interest lies in the intact cervical region; and although, during the subsequent removal of the portion of the cervical cord which had been left, the roots of what ultimately proved to be the single representative on the right side of the 4th and 5th left cervical nerves were found to be torn across at their point of exit from the dura mater, even this, though particularly annoying, makes no difference to the accurate description of the parts.

Some irregularities of the spines and laminæ of the cervical vertebræ having been observed during the dissection of the back, and a well-developed pair of 13th ribs discovered, a careful examination was made of the 1st rib region and the brachial plexus; with the result that the 1st ribs were found to be entirely ordinary in appearance, and the plexus apparently normal on the left, but postfixed on the right. This condition was seen to be associated with a reduction of the number of the cervical nerves on the right side to seven; and, as the transverse processes numbered only six, it

was thought that there might be complete absence of half a vertebra, a supposition which was subsequently proved to be correct.

It was found, further, that the 13th ribs were associated with the presence of an additional true thoracic vertebra, the lumbar and sacral regions possessing five each, and the coccygeal four segments. The vertebral formula is therefore C6½T13L5S5Co4 (fig. 1).

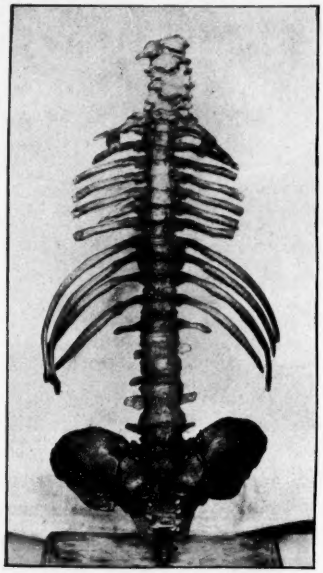

Fig. 1.—Vertebral column. C6½T13L5S5Co4.

The objects of this paper are: (1) to describe the vertebral column, the portion of cervical spinal cord, and some associated structures, with a short account of previous records of similar vertebral deficiencies; (2) to discuss the causation of the condition, and note its surgical interest.

PART I.

The Vertebral Column.

Cervical (figs. 2 and 3).—The main interest lies in the cervical region, as there is a clear and complete absence of the right half of the 3rd vertebra. As a result of this absence there is a lateral curvature of the whole region, complicated by firm ankylosis of the remaining left half of the 3rd with

the 4th and 5th vertebræ. There is also some distortion of the other cervical vertebræ, and all show considerable lipping of the bodies and articular processes, such as is often found in the neck of old subjects. The lipping of the bodies is best developed where support is required as a result of the curvature, the upper border of the 6th being pulled out on

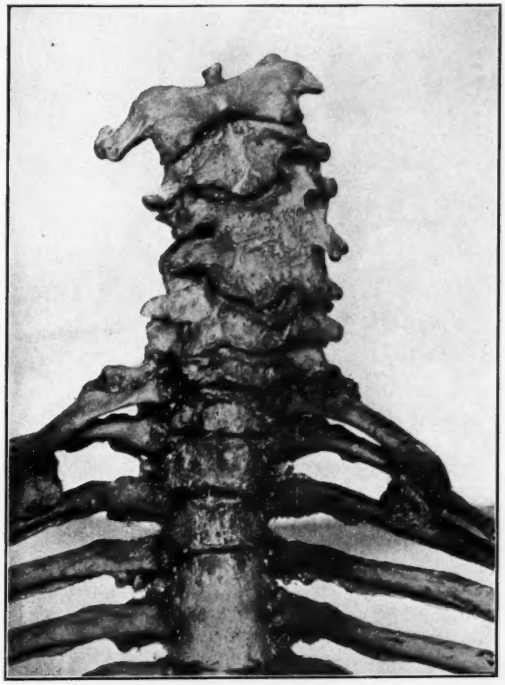

FIG. 2.—Cervical and upper thoracic region. Note the 1st ribs and the ankylosed vertebræ.

the left side, the lower on the right, to form strong buttresses, corresponding depressions being found above and below.

The ATLAS is stout, the posterior arch being especially thick, with a bifid tubercle; the left transverse process is partially broken off.

The AXIS possesses a well-marked occipital facet on a small process of bone separated from the main part of the odontoid process by a shallow constriction. Of the inferior articular surfaces, the right is rough and irregular, measures 18 mm. coronal × 9 mm. sagittal, and extends on to the

lamina and posterior part of the transverse process; the posterior portion looks directly downwards. The left is small, oval, slightly concave, and somewhat smooth; it measures 7 mm. coronal × 9 mm. sagittal.

The right lamina is deeper than the left, and both parts of the spine, which is strong and bifid, are twisted to the right.

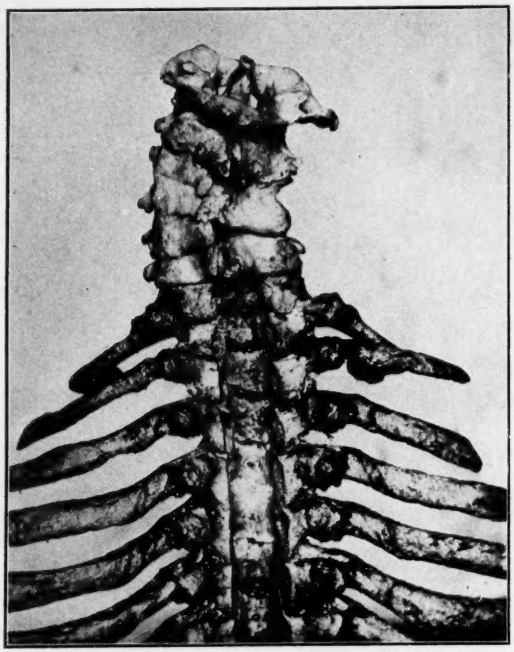

Fig. 3.—Cervical and upper thoracic region.

Composite Piece (R., 3rd and 5th; L., 3rd, 4th, and 5th).—*Bodies.*—The 2½ bodies are fused to form one mass. The lines of fusion between the two halves on the right side, and between the 4th and 5th halves on the left, are distinctly visible in front and partly behind; but the lines between the upper half on the right and the 3rd and 4th halves on the left are not so distinct, and it is impossible to decide whether the odd half is 3rd on top of 4th, or 4th wedged between 3rd and 5th. On scraping the upper surface, however, the appearance, especially from behind, was such as to suggest that the odd half belongs to the 3rd vertebra (fig. 4).

An X-ray photograph (fig. 5) shows clearly the line between the two

right halves, and also between the three left halves, but there is no clear line between either of the 3rd and 4th left halves and the upper half on the right side; and, as the lower left half apparently projects as much below the right half as the upper left half does above it, the appearance is such as to suggest that the right half may correspond to either of the left halves, or indeed to both, *i.e.*, that the condition is doubling of the left half of a single vertebra. This appearance in the X-ray photograph is, however, largely due to a superficial indentation on the anterior part of the lower border of the 4th vertebra, and on examining a coronal section through the middle of the fused mass, the line representing the intervertebral disc

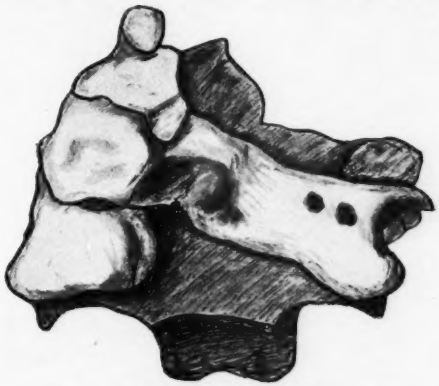

Fig. 4.—Composite piece, posterior aspect.

between the 5th and the two halves above it is seen to be nearly straight though oblique, thus strengthening the suggestion that the odd half is the upper and belongs to the 3rd vertebra. It will be seen later that the arrangement of the nerve roots upsets this suggestion, and, in fact, as the right nerve which corresponds to the 4th and 5th left emerged *between* the two right halves of the composite piece, it is proved that the upper half must be the 3rd, and as there is no question that the lower part is a complete 5th, the absent half *must* be *4th*. Such a conclusion drawn from the bones alone could only have been a matter of opinion.

Transverse Processes.—There are two on the right side and three on the left, the upper left being associated with the pedicle and half-body of the 3rd in the usual way. The foramina transversaria are distinctly larger on the right side, that of the 5th on the left side, encroached on by lipping of the body, being the smallest. There is partial subdivision of the 4th left by a tiny spicule springing from the medial end of the posterior bar of the transverse process.

The *pedicles* and intervertebral foramina call for no special remark, save that the right 4th–5th foramen is partially subdivided by a small bar of bone stretching from the back of the right side of the 5th body to the 5th pedicle near its posterior end.

Fig. 5.—X-ray photograph from the front.

Articular Processes.—The surfaces of the superior, of which the right, belonging to the 4th vertebra, is large, rough, and with lipped edges, and the left, belonging to the 3rd vertebra, is small and smooth, are similar to the inferior articular surfaces of the axis already described. The right, of which the posterior portion looks directly upwards, extends towards the body and laterally overhangs the vertebral notch and a deep groove on the side of the fused arches, extending medially half-way along the lamina. The inferior, both belonging to the 5th vertebra, are fairly

equal in shape and size; the right is slightly concave, the left flat, distinctly lipped laterally, and slightly eburnated. Of the others, on the left side fusion is only partial, particularly between the 4th and the 5th, and there is not much alteration in relative position; on the right side there is complete fusion, of which there is only slight indication towards the intervertebral foramen. The portion of the arch bearing them is compressed so that there is a deep groove overhung by superior and inferior articular processes.

Laminæ (figs. 3 and 4).—On the left side the three are distinctly seen, as they are only partially fused together. Their greatest depths are: 3rd, 10 mm.; 4th, 12 mm.; 5th, 15 mm. The 3rd slightly overlaps the 4th near the spines, and there is a distinct interval, 8 mm. long, between the 4th and the 5th near their middle. The 3rd and the 5th both end free in a half-spine, the 5th being much more prominent and in the middle line, which the 3rd just fails to reach. The 4th, maintaining its depth, is fused to a plate on the other side only slightly deeper and representing the 4th and 5th right laminæ.

On the right side the two laminæ are almost completely fused, the composite nature of the resulting lamina being indicated only by two small foramina near the lateral end and about one-third from the superior border, and by three smaller still at the medial end and near the middle. The greatest depth of the plate is 18 mm., and it narrows only slightly at the medial end, where it is fused, as stated, to the 4th left lamina. The resulting composite spine has been slightly damaged by the saw, but there is clear indication that it is bifid and that the left half is double.

Sixth Cervical.—*The body* is very irregular; it measures antero-posterior 2 cm., transverse 3·3 cm., posterior depth 1·4 cm. right, 7 cm. left. Its anterior edges are markedly lipped, the superior on the left, the inferior on the right side, in each case a process of bone convex anteriorly and roughly concave posteriorly coming in contact with and overlapping the corresponding edge of the 5th and 7th. The superior of these processes is supported on two rounded pillars of bone which project on the front of the body with a small recess between them. Both superior and inferior faces are extended by the lipping, and on the left side the superior is markedly deepened, the inferior irregularly convex. The right *transverse process* is a trifle more broadly spread than the left, and a spicule cuts off a small posterior part from the foramen in each. The left pedicle is apparently shortened by the overhanging of the lipped body.

Articular Processes.—The surface of the right *superior* (1·4 × 1 cm.) is fairly regular, the left (·7 × ·7 cm.) is smaller, irregular, and eburnated. The left inferior (1·1 × 1 cm.) is also irregular and slightly eburnated, and

the anterior portion looks directly downwards; the right (1·3 × 1·2 cm.), not so irregular and not eburnated, resembles the right superior. The left processes are nearer each other than the right, the depth of the articular column being fairly normal on the right, but shortened on the left; from the highest point of the superior to the lowest of the inferior is on the right 2·4 cm., on the left 1·7 cm. The general feature of the 6th cervical is therefore that it is deeper on the right side than on the left, as seen in body, laminæ, and articular processes.

The 7TH CERVICAL repeats the features of the 6th, though in a less marked degree. The body measures in depth on the right 1·3 cm., on the left 1 cm., while the articular columns are, right 2·5 cm., left 2 cm. The left superior articular surface is markedly convex from before backwards and outwards; the anterior portion looks directly upwards. The laminæ and spine are lost.

The right *lamina* (1·5 cm. at both ends) is slightly deeper than the left (1·5 cm. at the outer to 1·1 cm. at the inner end). The spine is slightly bifid and twisted to the right.

The following are the measurements of the articular surfaces:—

	Right.		Left.		
	Coronal.	Sagittal.	Coronal.	Sagittal.	
2nd Inf. . .	1·8 cm.	1·6 cm.	·7 cm.	·9 cm.	
3rd, 4th, 5th L. Sup. . .	1·9 ,,	1·9 ,,	·7 ,,	·9 ,,	
4th, 5th R. Inf. . .	1·4 ,,	1·0 ,,	1·2 ,,	1·1 ,,	1·5 (oblique)
6th Sup. . .	1·4 ,,	1·0 ,,	·7 ,,	·7 ,,	1·0 (oblique)
Inf. . .	1·3 ,,	1·2 ,,	1·1 ,,	1·0 ,,	
7th Sup. . .	1·3 ,,	·8 ,,	1·1 ,,	1·4 ,,	

The greatest disproportion occurs between the inferior surface of the composite piece and the superior of the 6th on the left side, and here presumably the greatest movement took place. It is noteworthy also that the articulations between the axis and the composite piece on the right and between the 6th and 7th on the left are partly horizontal, the latter more so. The question of the mechanism of the adaptation of the vertebræ to the restricted movements is not further entered into.

The THORACIC VERTEBRÆ do not require much detailed description. There is still some lipping of the bodies of the 1st and 2nd, and ankylosis of the bodies of the 4th and 5th; they are not united behind, and the line of union is elsewhere indicated by a ridge. The 9th has two incomplete

facets on each side of the body, the 10th one incomplete facet, while the 11th has a complete facet nearly on the pedicle. The 12th has a complete facet on the pedicle and none on the transverse process, and the 13th is similar in all respects to an ordinary 12th. It has three tubercles on the transverse process, the superior articular processes look mainly backwards, and the lower, though lost, must have been turned outwards, as the superior of the next vertebra look inwards. It will be seen that the 10th, 11th, 12th, and 13th vertebræ correspond to the ordinary 9th, 10th, 11th, and 12th.

Ribs.—Both *1st ribs* articulate with the 1st thoracic body, and to a considerable extent with the intervertebral disc above it, the left just failing to reach the body of the 7th cervical. The left is a little larger in nearly every respect than the right, as the following table of measurements shows:—

	Right.	Left.
Greatest length (tubercle-tip) . .	7·3 cm.	8·4 cm.
Least „ (head-tip) . . .	5·8 „	6·3 „
Inner border	8·5 „	9·4 „
Outer border (omitting tubercle) .	11·1 „	12·5 „
Breadth:		
Tip	1·6 „	1·7 „
Tubercle (greatest) . . .	1·9 „	1·9 „
Neck (least)	·8 „	·8 „
Subclavian groove . . .	1·7 „	1·6 „

The subclavian groove is distinctly divided into two portions on each side. In the posterior lay on the right side the 1st and 2nd thoracic, on the left the 1st thoracic contribution to the brachial plexus. The inner border of the rib is rounded opposite the posterior part of the groove, and nearly sharp opposite the anterior part in each rib. The anterior part of the edge is distinctly sharper on the right side; the posterior part of the edge is more rounded, and the posterior part of the groove a trifle more distinct on the *left*. It will be noted also that, although the left rib is in all other respects larger than the right, it is slightly narrower at the subclavian groove.

Ribs 2–8 right and 2–10 left are incomplete. The 5th pair articulate with the fused bodies of the 4th and 5th vertebræ; the 10th pair with the bodies of the 9th ($\frac{1}{3}$) and 10th ($\frac{2}{3}$) and the intervening disc; the 11th pair with the 11th vertebra and very slightly with the disc above; and the tubercle articulates with the transverse process. The 12th and 13th articulate with facets on the pedicles of their respective vertebræ and not with the transverse processes.

The following are the measurements of the last three ribs:—

	Right.	Left.
11th . . .	22·8 cm.	22·5 cm.
12th . . .	18·0 „	17·5 „
13th . . .	4·8 „	5·2 „

The sternum was unfortunately not preserved.

Muscles. — There was a well-developed psoas minor on each side attached to the 13th thoracic and 1st lumbar bodies. The quadratus lumborum was attached to the body of the 12th thoracic, and to the 12th and 13th ribs. The diaphragm was not attached on either side to the 13th rib, the costal fibres ending on both sides by blending with the transversalis tendon half an inch medial to the tip of the 12th rib. There was no "ligamentum arcuatum externum" on either side, and no well-defined "ligamentum arcuatum internum," as the line of origin of the psoas minor from the 1st lumbar and 13th thoracic bodies was also the line of origin of the lateral part of the crus of the diaphragm. On the right side a fairly large hiatus was left between the attachment to the 12th rib and to the outer border of the psoas, but it was subdivided vertically by a narrow muscular band blending with the transversalis tendon; on the left side a similar hiatus was partially closed by muscular fibres arching transversely across from the 12th rib to blend with the lateral part of the crus over the psoas.

Lumbar (fig. 6).—All the laminæ and some of the articular processes are lost. The left transverse process of the 1st has a thickening transverse to its length extending right across in front and over the lower half behind, and projecting above and below as a small knob. The 2nd has lost the left half of its neural arch. The 3rd right transverse process shows a thickening similar to that on the 1st left. The transverse processes of the 4th are smaller than those of the 3rd and distinctly triangular, the left being the narrower and more pointed; they are attached to the pedicles only. The transverse processes of the 5th, stout and pyramidal, spring from the side of the body as well as from the pedicle; their superior surfaces are on a level with the posterior part of the crest of the ilium.

Length of Lumbar Transverse Processes.

	Right.	Left.
1st	2·0 cm.	2·0 cm.
2nd	2·6 „	...
3rd	2·7 „	2·65 „
4th	2·5 „	2·0 „
5th	1·7 „	1·5 „

Bitransverse Measurements.

1st	7·8 cm.
2nd	...
3rd	9·6 „
4th	9·1 „
5th	8·7 „

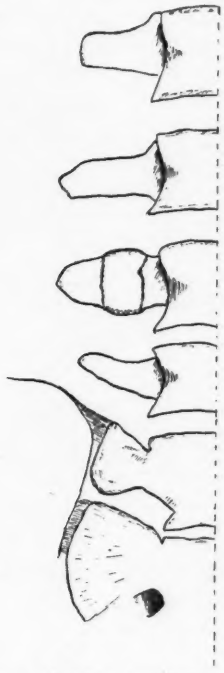

Fig. 6.—Lumbar transverse processes.

It is to be noted that the relative size and shape of the lumbar transverse processes are similar to those found in an ordinary set of five lumbar vertebræ, viz., a steady increase in length to the 3rd, a shorter and characteristically upturned 4th, and the highly characteristic 5th attached to both pedicle and body.

Sacrum 5, Coccyx 4.—The sacrum, unfortunately, was broken through the middle and a small portion lost, but the amount of damage done was not sufficient to prevent a satisfactory reconstruction; it consists of five pieces and requires no special remark. The four pieces of the coccyx are

fused together, and the whole ankylosed to the sacrum at an angle convex forward. The following are the transverse measurements of the coccygeal segments: 1st, 3 cm.; 2nd, 1·8 cm.; 3rd, 1 cm.; 4th, ·4 cm. The 1st has small transverse processes grooved in front but no trace of cornua. The 2nd has rudiments of transverse processes, and the 3rd and 4th are rounded, the 4th being very small.

Curvatures of Column as a Whole (fig. 1).—In the cervical region there is a well-marked convexity to the left, greatest opposite the point

Fig. 7.—Photograph of ventral aspect of cervical spinal cord.

where the half-body is missing on the right side. In the thoracic there is a slight convexity to the right, with a diminution opposite the fused 4th and 5th bodies, and in the lumbar a moderate convexity again to the left, greatest opposite the disc between the 2nd and 3rd bodies.

Spinal Cord (figs. 7 and 8).—A portion of the spinal cord, extending from the 2nd to the 8th cervical segment, has fortunately been preserved. On opening the dura and arachnoid it was seen to have a slight curvature convex to the left, corresponding to the curvature of that part of the canal in which it lay. The 4th and 5th nerve roots of the left convex side are arranged in the ordinary manner in their relation to the cord itself, the

ligamentum denticulatum, and the dura mater. The rootlets on the concave right side, corresponding to the 4th and 5th left, converge to pierce the dura mater at a single point to form what is the 4th nerve in series on that side. The area of origin of the rootlets of this nerve is slightly overlapped both above and below by the area of origin of the 4th and 5th left combined. There is one dentation of the ligamentum denticulatum fewer on the right side, the upper rootlets of the nerve running downwards very

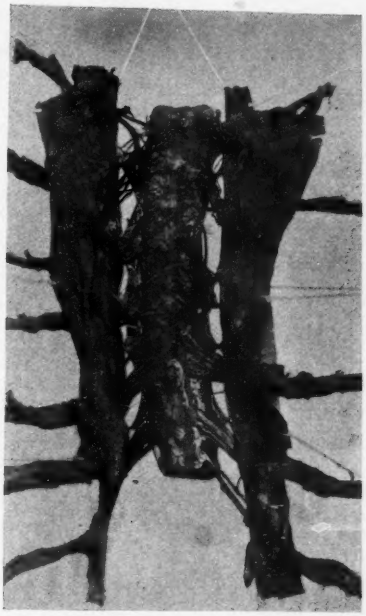

FIG. 8.—Photograph of dorsal aspect of cervical spinal cord.

obliquely to pass below the dentation which, corresponding to two on the left, is situated almost exactly opposite the interval between them, and therefore nearly opposite the point at which the left 4th nerve roots pierce the dura. The lower rootlets run nearly horizontally. As stated in the introduction, the roots are broken just at the point of piercing the dura, but their general course, the position of the opening in the dura, and their relation to the ligamentum denticulatum are perfectly clear.

Areas of Origin of Nerve Roots.

		Ventral.	Dorsal.
"4th"	Right	1·8 cm.	2·1 cm.
4th and 5th	Left	2·2 „	2·4 „

Ligamentum Denticulatum.		*Interval between Points.*	
Left.		Right.	
3rd and 4th . .	1·5 cm.	3rd and 4th . .	2·0 cm.
4th and 5th . .	1·1 „		
5th and 6th . .	1·0 „	4th and 5th . .	1·4 „
	3·6 cm.		3·4 cm.

The origin of the spinal accessory nerve appears to extend to about the same point on both sides: on the left to the interval between the origins of the 4th and 5th dorsal roots; on the right to the middle of the origin of the "4th" dorsal root.

NERVES.—The record of the dissection of the nerves is not as complete as might be wished, but the following essential points were noted. The brachial plexus, "normal" on the left side, was "postfixed" on the right. It was formed on the left side by the 5th, 6th, 7th, and 8th cervical, and 1st thoracic, with a small communication from the 2nd thoracic; the phrenic nerve arose mainly from the 4th cervical. On the right side the plexus was formed—taking the cervical nerves in numerical order as found—by the 5th, 6th, and 7th cervical, 1st and 2nd thoracic, the phrenic arising mainly from the 4th. But, remembering that the 4th right nerve represents two nerves, and renumbering the others with that fact in view, the plexus really arises from the 6th, 7th, and 8th cervical, 1st and 2nd thoracic, and the phrenic nerve arises mainly from the "4th," the doubtful nerve.

There is thus an inequality of one nerve in the formation of the brachial plexus on the two sides, but this inequality does not affect the formation of the other plexuses.

There are thirteen pairs of thoracic nerves, and, taking the 13th as equal to the ordinary 12th, the arrangement caudal to this point is in the main quite usual. The lumbo-sacral cord was formed on each side by the 4th and 5th lumbar nerves, the 25th and 26th spinal nerves, allowing again for the absence of the 3rd right cervical. The obturator and femoral nerves were both formed on each side from the 2nd, 3rd, and 4th, while on both sides the genito-femoral was traced to the 1st only, and the lateral cutaneous to the 1st and 2nd.

Similar Deficiencies Previously Described.

The deficiency of half a vertebra has not been often recorded, and never before with the corresponding portion of the spinal cord, or indeed with any mention of the associated nerves at all.

Rokitansky appears to have been the first to record deficiency of a half vertebra, in the 3rd volume of his *Pathological Anatomy*, 1842–46; yet he writes as if it were a well-recognised cause of scoliosis. "An allied deficiency, in which one or more vertebræ or half vertebræ are of small size or altogether absent, sometimes co-exists with other malformations," but "sometimes occurs in persons who are otherwise naturally formed." "It is interesting to observe in persons who are in no other way deformed, how the want of one-half of a vertebra, in the same manner as a half too much, produces congenital lateral curvature." "Excess of development is exemplified in the presence of an unusual number of whole or half vertebræ. . . . An excess of one or more halves of vertebræ occasions a congenital lateral curvature, in the same manner as a deficiency of halves of vertebræ; and it constitutes a most remarkable instance of scoliosis, of which I shall treat more at large hereafter." "Sometimes the curvature results from deficiency of the lateral half of a vertebra, or from unequal development of the two halves of the column, or from the presence of one or more half vertebræ too many."

He described three cases. (1) In the first (C7T11½L4SC—), a tailor aged 70, the lower six cervicals are united into one piece; the right half of the 9th thoracic is wanting, and the left half united to the 8th. The last lumbar is sacralised. (2) The second is a kyphotic spine occurring in a female, aged 55, as a result of the 12th thoracic vertebra consisting of two divided lateral halves; the triangular rudiments lie between the 11th thoracic and the 1st lumbar, points inwards, and are united to the latter. (3) The third is the most remarkable—compound scoliosis occasioned by the presence of supernumerary lateral halves of vertebræ which "compensate" each other. The spine, of a female aged 46, is in the Museum at Vienna, and was described by Rokitansky as "a very old preparation." There is a half vertebra between the 5th and 6th thoracic; the 7th thoracic and the 1st sacral are double on the left side, the 1st lumbar on the right. The laminæ terminate in a row of asymmetrical spines from the 1st thoracic to the 2nd lumbar. There are thus four half-arches too many; and the formula apparently is C7T13L6S5C—, there being thirteen pairs of thoracic ribs and a pair of cervical ribs. There is ankylosis between the odd half-arches and the bones next them, between several of the bodies,

especially in the concavity of the curvature, and also between the 2nd and 3rd cervical vertebræ.

Humphry, although he had himself examined many fœtal spines with great care and had never found anything but a single nucleus, collected evidence in 1858 to show that the body of a vertebra may sometimes develop from a double nucleus. He mentions a number of instances of double vertebral bodies which he had seen in museums, occurring in spina bifida and other malformations; quotes two of Rokitansky's cases; and gives in addition two others. One is deficiency of the left half of the 11th thoracic, recorded by Otto. In the other, figured by Sandifort, there is absence of half of the bodies of the 7th cervical, 9th and 11th thoracic; "the remaining halves are wedge-shaped, and some of the bodies lower down have two distinct nuclei, one on either side."

Dr James Goodhart recorded in 1875 several cases of malformation associated with extreme deficiency of vertebral segments. (1) In the first of these, a male aged 64, there is fusion from the 7th cervical to the 4th thoracic, and "the left halves are in a somewhat rudimentary condition.' The whole of the body of the 1st lumbar, the left half of the 12th thoracic, and the right half of the 2nd lumbar are wanting, in each case the transverse processes being represented; the two halves of the 4th lumbar body are not joined in the middle line. There is a 13th rib on the left side, the 12th being "unusually long" on both sides. (2) The second is a hydrocephalic male fœtus with only $4\frac{1}{2}$ cervical bodies, the odd half being the lowest. Each body consists of two rounded masses distinct from each other as far as the 9th thoracic; the laminæ are widely separated. (3) The third, an adult column, again shows distinct development of the bodies from two centres and the difficulties that may arise in interpretation through cross ankylosis of these centres. Goodhart also mentions two other cases, both fœtal, in one of which there was "an odd half vertebra developed in excess," in the other "fusion of superimposed halves of two vertebræ on the left side about the 8th dorsal," and he comes to the conclusion that "cases of asymmetry are due to original malformation of the bodies in the direction of bilobed or double nucleus, and subsequent unequal growth."

Struthers in his description of vertebral variations in 1875 does not mention absence of half a vertebra.

Willett and Walsham in 1880 described a case, in a woman aged 31, of sharp lateral curvature, with convexity to the left in the upper thoracic region, due to the absence of $4\frac{1}{2}$ thoracic vertebræ, including the right half of the 3rd, the 4th left and 5th right ribs being also wanting. The authors say that "the absence of half a vertebra has generally been ascribed to

defects in the process of ossification," and suggest that it must be due to changes occurring at an earlier period of development, "probably at the time of the primary segmentation."

Sir W. Turner recorded in 1886 a vertebral column in which the 10th thoracic body is represented by two wedge-shaped pieces, each with a facet for the 10th rib and continuous with a pedicle, a condition similar to one of Rokitansky's cases.

Professor Reid in 1887 figured and described a specimen to which no history is attached. The right half of a vertebra is wedged in between the 8th and 9th complete thoracic vertebræ. The body, the superior articular processes, and the well-developed lamina and half-spine are fused with the corresponding parts of the 8th, the inferior articular processes with the 9th. From the fact that the specimen is isolated it is impossible to say whether this half vertebra is additional, or the remaining half of a deficient vertebra. There is a well-marked intervertebral foramen both above and below it.

Professor Paterson and Dr Lovegrove recorded in 1898 a fœtal column in which the left half of the 7th thoracic body is wanting; and another in which, the bodies being normal, there is a mixing of the laminæ.

Professor Dwight, in the introduction to his account of forty-five anomalous spines in 1901, mentions "a lateral half of a sacrum which probably had an extra half vertebra on one side"; and refers to the python,[1] discussed also by Baur and by Bateson, and figured by the latter, in which the 166th and the 185th vertebræ are each double on one side, with two transverse processes and two ribs.

Since the introduction of X-rays a number of cases of congenital scoliosis have been ascribed to absence of half a vertebra.

Mouchet in 1898 appears to have been the first to record such a diagnosis, in a girl aged 2, in whom he found "an extra half vertebra between the 1st and 2nd lumbar." The following year he recorded "an extra half" in exactly the same position in an anencephalic female fœtus.

He was followed by Codivilla, who in 1901 described "an extra half between the 2nd and 3rd lumbar" in a girl aged 11. In the same year Fleury wrote a thesis on another case in which it was afterwards shown

[1] This python is in the Royal College of Surgeons of England Museum, and I am indebted to Professor Keith for information regarding it. Professor Keith also pointed out to me that the vertebral column here described exhibits irregularities very similar to those that occur in congenital elevation of the scapula (Sprengel's shoulder). Particular attention was, however, paid to this possibility by Professor Jamieson when the abnormalities were discovered, as he had recently seen a case of the condition clinically; there was no suggestion that the scapulæ were displaced nor any abnormality of them. We discovered later that the man had been in the army, so that the shoulders must have appeared fairly regular during life.

by Mouchet and Broca that the left half of the 12th thoracic was absent.

In 1909 Mr Duncan Fitzwilliams, from whose paper the particulars of these cases of congenital scoliosis diagnosed by X-rays have been obtained, called attention to the subject by the publication of his case in a girl aged 16 months. The mother had noticed the deformity since birth; neither rickets nor spinal caries was present, and an X-ray photograph revealed a wedge-shaped vertebra between the last thoracic and the 1st lumbar. There were apparently six lumbar vertebræ. In the following year Dr Frederick Langmead recorded a similar case in a girl of 10 months. Since then a number of cases have been recorded, but in all the evidence has consisted of the X-ray picture only; in none, so far as I am aware, has there been any subsequent post-mortem examination, and consequently no accurate account of the condition of the bones, and none of the spinal cord and nerves.

PART II.

Absence of Half a Vertebra.

The actual numerical position of the odd half vertebra had to be determined, and although, as already mentioned, there was at first some little doubt, it became quite clear that it belonged to the 3rd. Next the question arises whether it is the remaining half of a deficient vertebra, or an additional half intercalated between the 2nd and 3rd, a question which insists on a definite answer when we find that there are thirteen thoracic vertebræ with normal lumbar and sacro-coccygeal regions. But if we look upon the odd half as an addition, then we have only six cervical vertebræ, or else the best developed pair of cervical ribs that could be imagined, so simulating the ordinary 1st ribs in every respect as to be indistinguishable from them. These ribs must, in fact, be considered ordinary 1st ribs unless we wish to ascribe a penetrating and absolute individuality to every member of the ordinary series of vertebræ. Had the 3rd cervical vertebra been completely instead of partly absent, the column would then have been an example of absence of a cervical vertebra and presence of an additional thoracic, *i.e.* the formula would in reality have been C6D13L5S5C4, without any question of the mere transference of the lowest cervical to the thoracic through the development of its costal element, a condition which Dwight hesitated to describe. Further, the conditions present in the portion of spinal cord preserved show that we are dealing with something that affects more than the bones, and it is clear therefore that presence or absence of half a vertebra is not a sufficient *explanation.*

Dwight defines intercalation as "the presence of an extra vertebra between two *particular* vertebræ," and Birmingham pointed out some years before that if a vertebra is intercalated there should be no nerve to one vertebra. In most of the discussions on intercalation this fact has not been properly appreciated, and the distinction between intercalation of a vertebra or portion of a vertebra and intercalation of a segment or portion of a segment has not been properly drawn.

We are probably dealing then with $6\frac{1}{2}$ cervical segments, and we have to consider how the loss of half a segment has occurred. Should we consider the bone alone we might simply say "defect of ossification," for there is clear evidence that the vertebral bodies are sometimes ossified from two centres; but remembering the condition of the spinal cord and the nerves, the main interest lies in these. Now, from the areas corresponding on the right side to the areas of origin of the 4th and 5th left nerves we have arising a single nerve, and the question then is whether the two have run together or if one is absent. If a nerve is absent, then it is clear that this cannot have been brought about by a defect of ossification, rather the deficiency of the bone will depend on the early fault of segmentation; whereas if two nerves have run together it is possible that this may have been caused by the defect of ossification on the converse of Birmingham's principle that if there is *excalation* of a vertebra there should be two nerves to one vertebra. It is, of course, possible that if two nerves were run together the resulting nerve might be smaller than the sum of the two original components, and also that, if a nerve be absent, the neighbouring nerves might be larger, so that the size of the nerve in question might be very nearly the same on either hypothesis.

As a matter of fact, the surface areas of origin, ventral and dorsal, of the "4th" right are less than the respective combined areas of the 4th and 5th left, and the number of distinct rootlets is: "4th" ventral, 7; dorsal, 9; against 4th and 5th ventral, 14; dorsal, 13. It is not likely either that the 2nd thoracic nerve would contribute so much to the brachial plexus on the right side only were the 4th and 5th cervical nerves merely run together, nor would one expect the very definite single point of exit from the dura mater for all the fibres, nor the regular arrangement of the ligamentum denticulatum. On the suggestion of Professor Robinson an attempt was made to count the fibres in the roots of the nerves in question, and although the results are far from having any absolute value, yet they contain in themselves evidence that they are at least *comparatively* trustworthy.[1]

[1] As the roots were much shrunken, it was impossible, after treating with osmic acid, to count any of the smaller fibres; hence the numbers arrived at are much below what is said to be the average, and this is particularly the case in the dorsal roots.

		Ventral.		Dorsal.	
Right	"4th" . . .	2390		4760	
Left	4th . . .	2940	3595	4430	4950
„	5th . . .	4250		5470	

The figures of the left 4th and 5th dorsal are in each case greater than the figures of the ventral root, and the counts of the two nerves are sufficiently near to justify a comparison with the right "4th." The

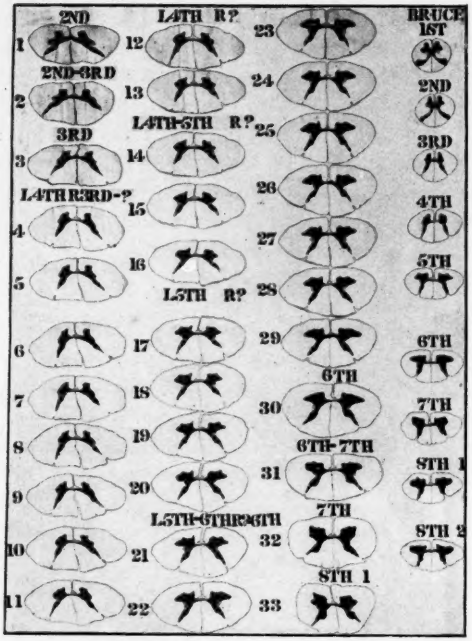

FIG. 9.—Photograph of outline drawings of serial sections of cervical spinal cord numbered consecutively; the level of the section is also indicated (see fig. 10). The typical series on the right of the figure are after Bruce's Topographical Atlas of the Spinal Cord.

figure for both ventral and dorsal roots of this nerve will be seen to be less than the average of the left nerves, a result which is in favour of the right nerve being single.

The spinal cord was also sectioned with a view to determining the different segmental levels, to find out if the irregularity of the nerves was paralleled in the cord; and if so, whether additional evidence could thus be obtained of the identity of the missing segment.

To preserve in series the parts into which the portion of cord was cut, the method recommended by Dr Edwin Bramwell was adopted, threading them on a horse hair passed through the left side of each part from above. Serial sections 16μ were cut, and stained deeply with hæmatoxylin. Outline drawings by projection were then made of every 10th section in

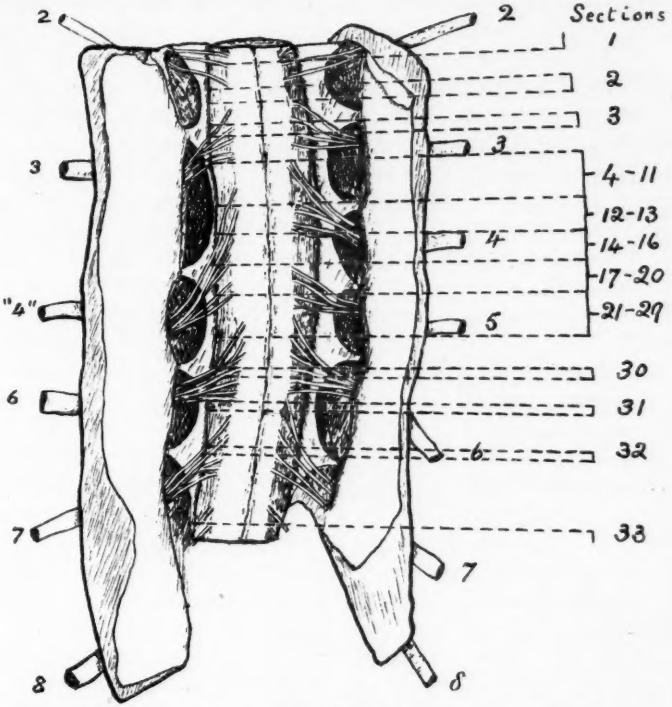

FIG. 10.—Ventral aspect of cervical spinal cord, with key to fig. 9.

the doubtful region, and above and below this of sections from the middle of each segment and the intervals between them. Fig. 9 is from a photograph of the drawings mounted in series; similar outlines (on a different scale) from the late Dr Alex. Bruce's Atlas of the Spinal Cord are shown for comparison. It should be noted that the cord was somewhat flattened antero-posteriorly; and that each section is looked at from above, so that the left side of the cord is on the left hand of the reader as indicated by the lettering in the figure. Fig. 10 is a key to the position of the sections.

The sections are numbered consecutively, and it will be observed that

the two sides are fairly symmetrical except from the 3rd to at least the 19th section. Looking at the left side of the sections first, it will be seen that they correspond closely to Bruce's types; the typical appearance of the 4th is best seen in sections 9 and 10, of the 5th in section 19; and sections 30, 32, and 33 clearly correspond to the 6th, 7th, and upper part of the 8th. On the right side the same sections, 30, 32, and 33, are again clearly 6th, 7th, and upper part of the 8th. The characteristic outlines of the ventral horns of the 6th, anvil-shaped, and of the 7th, rhomboidal, are clearly seen on both sides.

Sections 12 to 20, which on the left side are from segments 4 and 5 and intervening portion, are on the right side through the portion of cord from which the doubtful nerve arises, and it is suggested that the outlines of these on the right are much more like the 5th all the way through, the characteristic outline of the ventral horn with double concavity and prominent antero-lateral and postero-lateral angles being well seen even in section 12. If, now, the right side of the sections be traced up from No. 11, which is just at the upper end of the origin of the doubtful nerve through the transition from that of the 3rd segment to No. 3, the double concavity can be traced at least as far as No. 8, and there is no appearance of the characteristically broadened 4th with rounded angles. The section through the 3rd segment (No. 3) is not very like the corresponding typical section on either side; the interpretation of the sections from 3 to 11 is difficult; but there can be no doubt that from 12th to 20th the right side is strongly suggestive of 5th all the way, while the left is definitely 4th above and 5th below.

A striking feature is the relative smallness of the right grey crescent from the 3rd to the 18th sections, and it is suggested that the study of these sections leads to the conclusion that the right half of the portion of the cord represented by sections 12 to 20 is one segment, and that segment the 5th, and that the 4th right segment is not represented.

Numerical Variation in the Cervical Region.

The cervical is a relatively stable region; apart from the subtraction or addition of a vertebra by greater or less rib development the number of its segments is remarkably constant.

The presence of eight cervical vertebræ followed by a vertebra bearing a pair of ribs with undoubted 1st thoracic characters is a rare condition. Dr Barclay Smith recorded a case in 1911, and mentioned a few others; but thinks that "in some of these instances the cervical excess is to be accounted for by the 1st thoracic vertebra evincing cervical characteristics,

the 1st rib being rudimentary." The undoubted cases appear to be those recorded by Sir W. Arbuthnot Lane, Leboucq (two cases), and Dr Barclay Smith.

The opposite condition—six cervical vertebræ followed by a vertebra bearing a pair of ribs with undoubted 1st thoracic characters—is even more rare. The only recorded case appears to be that of Dwight (13), and he expresses doubts whether the ribs are to be considered cervical or thoracic. Leboucq stated that in his belief the addition of a vertebra in both his cases is due to an intercalation after the axis, and in one of them thought this to be the result of reduplication of the axis. Dwight discusses this point, and comes to the conclusion that there is no reason to see anything more than fusion. "Leboucq," he goes on, "asks whether we are to consider his finding twice an intercalated vertebra at this place anything more than a simple coincidence. He thinks that the place below the axis is a critical one in the cervical column, and that the 3rd vertebra is exposed to more variations than the others. He cites Murie to the effect that the reduction of the cervical vertebræ to six in the manatus arises from an almost complete regression of the 3rd."

In both Leboucq's cases, further, the axis and the 3rd vertebra were fused together, a condition also present in the case of eight true cervicals described by Dr Barclay Smith. Nor is this synostosis of axis and 3rd confined to the cases of additional cervical; it has also been described in cervical regions with the normal number of vertebræ by Rokitansky, Goodhart, Arbuthnot Lane, Dukes and Owen, and by Dwight, who has seen it four times. Thus we have eleven cases altogether of fusion at this point, and the evidence is strong that it is a critical point. It was thought at first, when the odd half vertebra was believed to be the 3rd, that the present instance rendered that evidence stronger. The odd half, however, proved to be 4th, and the 3rd is fused not to the axis but into a composite mass with the succeeding one and a half vertebræ. This fusion can hardly be taken as part of the evidence of the inherent instability of the region, in view of the more obvious suggestion that it is a reaction to the acute curvature produced by the absence of the half vertebra. Whether the fusion was congenital or developed later hardly affects the argument; it is accompanied by osteoarthritic disease, which also may owe its origin to the extra stress involved by the curvature, but is in any case common enough in the neck of old subjects.

The mixing and fusing of the laminæ is not in itself an essential feature, as it occurs in cervical regions with the ordinary number of vertebræ and no fusion of the bodies. Such cases have been recorded among others by Paterson and Lovegrove in the fœtus, and Dwight in the adult.

First Ribs.—It has already been pointed out that the 1st ribs are typical in every respect (fig. 2). A glance at the table of measurements will reveal some interesting points when taken in conjunction with the condition of the nerves. It will be noted that the left is larger than the right save in the one point, that it is narrower at the subclavian groove. The posterior part of the groove is also more distinct and its inner edge rounded, and yet it is not on this side but on the other that the brachial plexus receives the large contribution from the 2nd thoracic nerve. That is to say that the rib on the side with the postfixed plexus, though slightly smaller on the whole than the other, is not so distinctly marked by the arching over it of large contributions from the 1st and 2nd thoracic nerves to the brachial plexus as the other rib is by the contribution from the 1st thoracic alone. This observation is in opposition to a far-reaching application of the views of Dr Wood Jones on the influence of the nerves in the moulding of these ribs, though the fact that the lowest cord of the plexus invariably lies in the posterior part of the groove may be taken as established. Dr Low has recorded the opposite condition, a rudimentary 1st rib on one side with a normal plexus on both; and Professor Wingate Todd has described a case in which a cervical rib, 8 cm. long, was present on each side and the plexus normally constituted on both. The slightly smaller size of the right rib *may* of course be associated with the postfixed plexus, but it is to be remembered that it is only *very* slightly smaller, and that the other abnormal conditions present are quite sufficient to account for the difference, which is indeed well within the range of differences between the 1st pair of ribs under ordinary circumstances.

Fusion of the Bodies of the Third and Fourth Thoracic (figs. 2 and 3).

The question of the origin of the synostosis at this point is of some interest. Is it purely accidental, is it a result of the mechanical conditions produced by the cervical lateral curvature, or has it some special significance in view of the fact that we have here an additional true thoracic vertebra? As for the mechanical suggestion, there is certainly a diminution of the thoracic lateral curvature at this point, but this is more likely a result than a cause, as such a diminution is not at all usual in scoliosis. There is, on the other hand, no evidence for the view that there is some special reason for this isolated synostosis. It is possible that there may have been reduplication of the 3rd thoracic, as Leboucq thought there was of the axis in one of his cases, but a number of measurements of the series of thoracic vertebræ compared with the normal measurements given by

Anderson and by Dwight do not indicate any unusual feature at this point. Measurements are, in any case, of little individual value, since there is no reason to suppose that the sizes of the different vertebræ are not entirely due to adaptation to the function of the column as a whole. Dwight indeed has shown in one case (C7T11L5S5C4) that the eleven thoracic vertebræ exceeded the normal twelve in length by 16 mm. In the column under discussion the average of the front and back measurements of the thirteen thoracic exceeds that of the normal twelve (as given by Dwight) by 3 cm., which is greater than the individual height of any one vertebra. Therefore, although it is true that in every case of abnormality of the column an effort appears to be made to discount the initial deficiency or addition of a part by a functional adaptation of the whole, yet this adaptation need not always have the thoroughly structural effect suggested by Dwight.

There is no evidence that there is an addition of a thoracic vertebra at any one point, but in view of the facts that there is undoubted absence of half a vertebra, and that, had the other half of the same vertebra also been suppressed, there would have been no evidence left that the vertebra had disappeared *at that point*, it is quite reasonable to suppose that addition or suppression may take place at a particular point, *i.e.* that "intercalation" and "excalation" are possibilities. We cannot, however, say more in this case than that there are thirteen instead of twelve vertebræ without ascribing individuality to the extra member of the series.

The Thirteenth Pair of Ribs.

It has been noted by Dwight that where the last pair of ribs is very short the penultimates are much longer than usual. These ribs are an instance, as the measurements already given show; it will be noted that the longer 13th is associated with the shorter 12th.

Lumbar, Sacral, and Coccygeal Regions.

The only difficulty in the sacral and coccygeal regions arose through the destruction of a small portion of the sacrum. As a result, there is a little doubt whether there are four or five coccygeal segments, a point which is of little importance. Of much more importance is the fact that the lumbar and sacral regions taken together are remarkably normal. There is no striking evidence, such as one often finds when thirteen ribs are associated with five separate lumbar vertebræ, that the 5th lumbar is really derived from the sacrum. The five lumbar vertebræ and the region

round the lumbo-sacral articulation are quite ordinary in appearance. The transverse processes particularly give one the impression that the vertebræ to which they belong are five ordinary lumbars (fig. 6).

For the sake of comparison, outlines of the lumbar transverse processes of four spines with different formulæ are given.[1] It is at the least unlikely that if the number of lumbar vertebræ has been made up to five by the addition of a segment from the sacrum, the five trans-

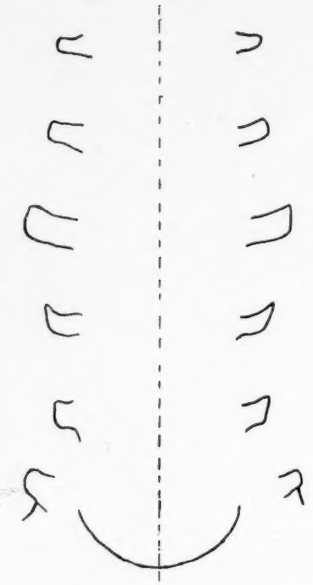

Fig. 11.—Lumbar transverse processes, spine A. C7T12L5S6Co4.

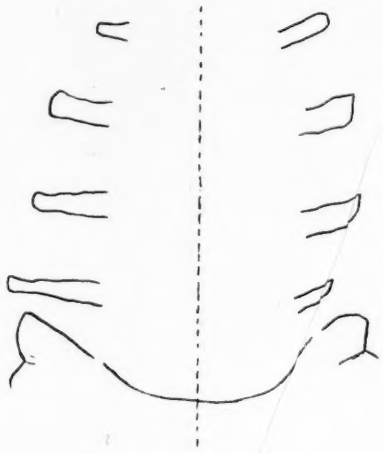

Fig. 12.—Lumbar transverse processes, spine B. C—T12L4S6Co—.

verse processes should exhibit exactly the characteristics of the ordinary five, and that the 4th in particular should not indicate that it represents the ordinary 5th.

Spine "A," C7T12L5S6Co4 (fig. 11).—The 1st piece of the sacrum is partially separated, the transverse processes being indicated. There is a slight angle between the body and the rest of the sacrum, and the inferior articular processes are free. The lumbar transverse processes increase in length to the 3rd; the 4th are smaller and turned up; the 5th

[1] These spines are in the Anatomical Museum of the Leeds Medical School.

short and stumpy, and attached to the body as well as to the pedicle. The spread from tip to tip is as follows:—

1st	6 cm.	
2nd	6·4 „	(estimated, as the tip of the right is broken).
3rd	7·8 „	
4th	6·8 „	
5th	6·4 „	
1st sacral	8·1 „	

Spine "B" (fig. 12).—This spine (C—T12L4S6Co—) exhibits the opposite condition, the last lumbar being partially sacralised. There is a well-marked angle, the transverse processes are only partially fused, and the laminæ and inferior articular processes are quite free.

The lumbar transverse processes increase in length to the 3rd; the 4th on the left side is small and triangular, but on the right is drawn out so as to be quite unusually long and thin. In spite of this, however, the spread of the 4th is not any greater than that of the 3rd pair. The transverse processes of the 1st sacral are clearly typical 5th lumbar. The spread is as follows:—

1st	6·8 cm.
2nd	9 „
3rd	9·8 „
4th	9·8 „
1st sacral	10·2 „

It should be noted that there is evidence of a cervical rib having been present on the left side.

Spine "C" (fig. 13).—In this spine (C7T13L4S6Co—) the 1st lumbar vertebra has a pair of ribs, and there is very slight separation of the 1st sacral. The 1st lumbar transverse processes are turned down slightly, the 2nd are straight and longer, the 3rd are a trifle longer again, but markedly turned up, while the 4th, also turned up, are thick and pyramidal and attached partly to the body. The spread is as follows:—

1st	8·0 cm.
2nd	8·6 „
3rd	9·0 „
4th	8·5 „
1st sacral	8·7 „

Spine "D" (fig. 14).—In this spine (C7T13L5S5Co—) the five lumbar vertebræ are quite ordinary in appearance; there is no evidence that the

5th has separated from the sacrum, the 1st sacral itself being in fact slightly detached behind. The transverse processes increase in the usual way in length to the 3rd; the 4th are typically short and triangular and upturned; the 5th pyramidal and attached to the body. This is another instance of a true additional thoracic vertebra, as it is extremely unlikely that the transverse processes would be so typically arranged were all the vertebræ moved one place upwards. By comparing the outlines of "D" with those of "C," where the 1st lumbar has been simply absorbed into the thoracic region, and those of "A," where there has been a partial move-

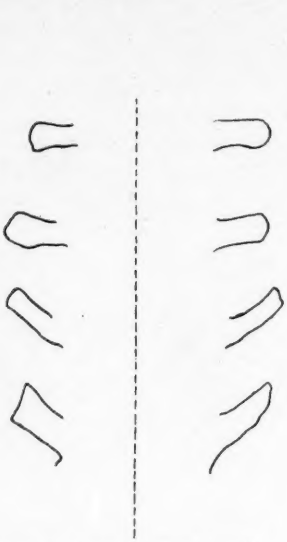

FIG. 13.—Lumbar transverse processes, spine C. C7T13L4S6Co—.

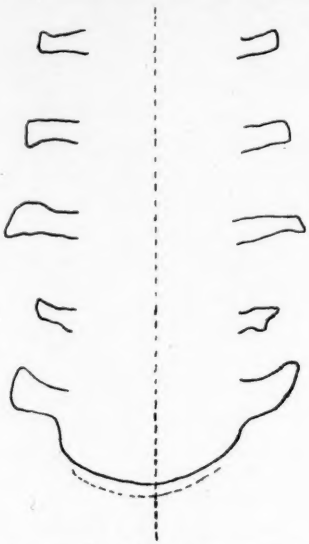

FIG. 14.—Lumbar transverse processes, spine D. C7T13L5S5Co—.

ment upwards but without the development of 13th ribs, this impression becomes very strong.

Lastly, compare "A" (fig. 11) and "B" (fig. 12), where the opposite conditions of lumbarisation of the 1st sacral and sacralisation of the 5th lumbar are exhibited, so that there is at least a whole vertebra length difference between the two, and yet the characteristics of the lumbar transverse processes are clear in both.

The question at once arises of the cause of the peculiar shapes of the lumbar transverse processes; and it may be suggested that as they depend upon the muscles attached to them, the shapes will vary with the relative

distances of the processes from the crest of the ilium and the last rib irrespective of the number of the vertebræ with which they are associated. There is certainly some truth in this, and it is not suggested that there are no such differences, only that there are indications which enable one to say, in the lumbar regions here figured at any rate, independent of the level in relation to the crest of the ilium or to the last rib, to which vertebræ the transverse processes should be assigned. There is therefore evidence that the shapes of the transverse processes of the lumbar vertebræ are not entirely due to the muscular attachments; that they have, in fact, a value of their own.

Surgical Interest.

This vertebral column has a considerable interest from a surgical and particularly diagnostic point of view. Of late years the general use of X-rays has resulted in a number of cases of scoliosis being diagnosed as due to congenital deficiency of half a vertebra, but this aspect of the subject is not entered into here beyond stating that none of the cases, so far as can be ascertained, have been verified post-mortem, and that in some it is doubtful if they are due to the cause stated.

The clinical history of the present case is interesting in that it is negative so far as the conditions described are concerned; he was twice in hospital during recent years, and nothing abnormal was noted about the neck on either occasion. It was further ascertained that he was in the army for a number of years, so that there can have been no marked deformity. For these details I am indebted to Dr James Allan, Medical Superintendent of the Leeds Union Infirmary.

Summary.

The anomalies here described are the absence of half a vertebra in the cervical region and associated deficiency of spinal cord and nerve. The absent half vertebra must either be the 3rd or the 4th, and it is proved from the arrangement of the nerves to be the 4th. It is suggested that the bone condition is secondary to the nerve abnormality; and from the external appearance of the roots, and the relative number of fibres contained in them, that a single nerve on the right corresponds to two on the left; and from the appearance of transverse sections of the cord that the single nerve is the 5th. The general conclusion is that there has been an error of segmentation involving the suppression of half a segment in the cervical and the addition of a whole segment in the thoracic regions;

that the two are directly connected there is no evidence, but it is reasonable to suppose that they are the effects of the same general cause.

I am much indebted to Dr Leo Rowden, Honorary Radiologist to the Leeds General Infirmary, for X-ray photographs; and I have to express my thanks to Professor J. Kay Jamieson for permission to publish this account, and for much advice and help during the progress of the work which it has entailed.

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APPENDICES EPIPLOICÆ AND PERICOLIC MEMBRANES.

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Apart from inflammation, adhesions found in the fœtus and young child are scarcely if at all less extensive than those found in the adult.

Practically all are developed whilst the parts are actively growing, and most obvious causes for their formation are the pressure exerted upon parts by the relatively enormous fœtal pelvic colon; the anchoring of or traction exerted upon parts, pulling or pressing them together, by the genito-mesenteric fold of peritoneum; and the firm resistance against pressure of the large liver, between whose visceral surface and the intestines and parietal peritoneum peritoneal sheets are "caught" and pressed together and adhere to one another and (as, for example, in the case of the stomach) to the parietal peritoneum. In short, in the production of an adhesion in the fœtus there must be relative fixation as well as pressing together of peritoneal sheets.

(1) *The Genito-mesenteric Fold.*—This adheres to the colon in the fœtus shown in fig. 1. In this fœtus it is clearly indicated that the pelvic colon is a cause of peritoneal adhesions as well as intestinal distortions. The pressure which it had exerted had undoubtedly caused the ascending colon to be bent upon itself; and the cæcum (which would have overlapped the pelvic brim had the colon been straight) had in this way been carried upwards and lay behind the pelvic colon (which had to be pushed to the left to expose it). The pelvic colon (which formed a *compressed omega-shaped* loop) also lay in contact with the genito-mesenteric fold, the lower part of which it had pushed towards the right off the line of the testicular vessels. The fold thus displaced was moulded over the colon to form a distinct pocket in which the flexure was lodged. Moreover, the pressure had caused the fold to adhere to what was originally the posterior surface of the bowel (we have seen that in some cases it may also cause it to adhere to the ileum, appendix, and cæcum), so that the colic flexure was rendered permanent in this remarkable manner.

When the bowel was shelled from the pocket the fold was seen to be roughly J-shaped. Its parietal border at first descended upon the testicular vessels, and at a point 1·7 cm. from the internal abdominal ring (annulus

inguinalis abdominalis) arched outwards for 1·3 cm. over the right iliac fossa. Laterally the fold bounded a small fossa (see fig. 1).

C. H. Mayo (see *Surgery, Gynecology and Obstetrics*, March 1911) believed that Jackson's membrane was formed by the rotating cæcum burrowing its way down behind the parietal peritoneum. This "is about the only hypothesis by which we can explain that form of Jackson's membrane which encloses the cæcum and ascending colon as in a bag"

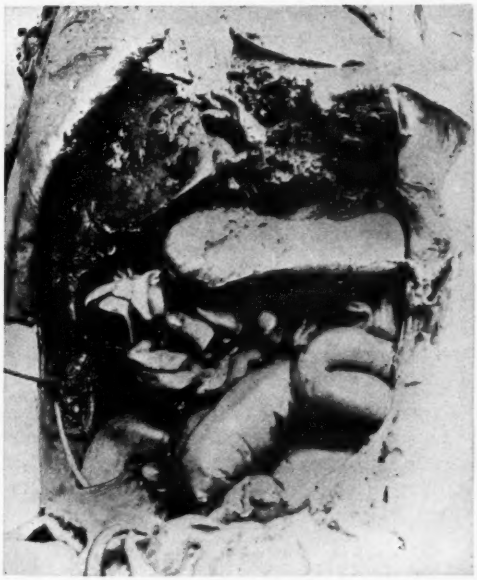

FIG. 1.—Fœtus No. 1, ♂, nine months old. The strip of white paper rests upon the ascending colon (indicated also by a needle), and its lower end lies in the outer part of the pocket formed by the genito-mesenteric fold of peritoneum. To expose completely the pocket and cæcum the *compressed omega-shaped* loop of pelvic colon has been pushed to the left.

(Eastman); and I have shown that the genito-mesenteric fold may actually be wrapped over the bowel (appendix, cæcum, colon).

(2) *The Great Omentum.*—In adult A (see fig. 2) the right part of the transverse colon is closely and firmly bound to the ascending colon by the great omentum, which crosses between and adheres to both parts of the bowel.

(3) *Appendices Epiploicæ.* (*a*) *In Relation to the Ascending Colon.*—I have already published a photograph of a strong pre-colic membrane

(present in an adult dissected at Cambridge, Lent, 1914), and have indicated that there could be little doubt that it was formed by an appendix epiploica.

In two of the twelve adults whose abdomens were dissected at Cambridge, May term, 1914, I found strong membranes lying in front of the ascending colon (see fig. 3); and narrower bands were present in several other specimens.

In adult B the membrane was especially strong and extensive (see fig. 3). It stretched from the cæcum (which was normally placed) upwards to the hepatic flexure, where it had no connexion with the great omentum. It passed from the parietal peritoneum (formerly ascending mesocolon) along

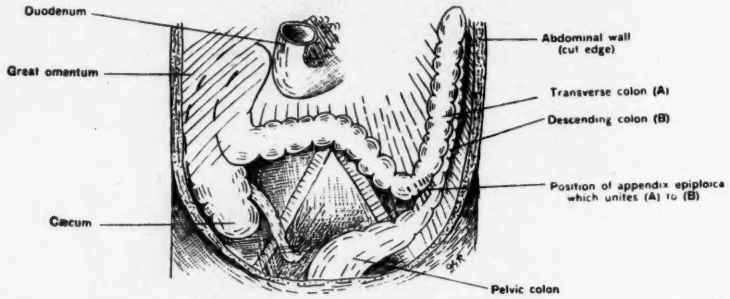

FIG. 2.—Adult A, ♀. The transverse colon is firmly bound to the ascending colon by the great omentum and to the iliac colon by an appendix epiploica.

the medial border of the bowel to end in a free margin which lay in contact with but did not adhere to the right lateral abdominal wall.

The anterior tænia coli was completely hidden, and at first it appeared almost as if the parietal peritoneum were continued from left to right across the anterior surface of the colon, whose outline was thus greatly obscured. The fold adhered loosely to the bowel, but did not bound a pre-colic fossa It contained a considerable amount of fat distributed fairly uniformly, and arteries (derived from the right and ileo-colic vessels) visible to the naked eye and coursing at right angles to the long axis of the bowel.

The cæcum was 6·5 cm. broad. The ascending colon was telescopic in form, being subdivided into three distinct segments of different width. The first, or lowest, was not separated from the cæcum by any constriction, but at a point 4·5 cm. above this it became suddenly constricted as it passed into the second part. This extended upwards to about the middle of the ascending colon. It averaged 32 mm. in breadth, and a distinct constriction marked its passage into the third or highest part, which varied from 22 to 28 mm. in breadth.

At the hepatic flexure the bowel expanded quite abruptly, and the transverse colon was 5 cm. broad.

The cæcum and lowest part of the ascending colon do not tend to be constricted, and in this as in other cases were not dilated. The walls of

FIG. 3.—Adult B, ♂. A knife has been placed behind the free edge of the large appendix epiploica which prolongs the membrane in front of the ascending colon. Another knife lies in a foramen formed by the adhesion of a strong appendix epiploica to the transverse colon. The descending colon is also hidden behind a strong and extensive membrane. The strip of white paper indicates the position of the medial border of the descending colon. A small remnant of the genito-mesenteric fold of peritoneum is indicated by another knife. Between this fold and the cæcum the ileum is permanently curved.

the bowel were healthy. The muscular coats of the cæcum and transverse colon were practically normal in thickness. The muscular coat of the

ascending colon was three times as thick as that of the transverse colon. Both its layers were much thicker than normal.

The large free fold of peritoneum (see fig. 3) which prolongs the right border of the membrane is especially noteworthy, for it is undoubtedly an enormous appendix epiploica; and there can be no doubt that the whole membrane was formed by at least one gigantic appendix epiploica.

I have already published illustrations showing that these enormous folds do occur in relation to the ascending colon. A still larger fold (11·5 cm. long and (in most of its extent) 4·5 to 5 cm. high) was present in one of the twelve adults referred to. It was attached to the colon along an oblique line extending from a point to the left of the anterior tænia coli, one inch above the ileo-cæcal junction, upwards to the parietal peritoneum immediately to the right of the hepatic flexure.

In another of these adults a strong but relatively small appendix epiploica crossed the ascending colon to gain attachment to the lateral parietal peritoneum. It is quite common to find narrow bands formed in this way; but only in this adult did such a band produce a distinct constriction of the ascending colon.

(*b*) *In Relation to the Descending Colon.*—In adult B (see fig. 3) a strong and extensive membrane was also present coating the descending colon and completely obscuring the anterior tænia coli. It extended across the bowel from the parietal peritoneum (formerly mesocolon) immediately along the right border (indicated by a strip of white paper) of the colon. It adhered to the bowel, but its left border was prolonged by free processes of peritoneum (appendices epiploicæ) which came into contact with the lateral parietal peritoneum. It contained fat and blood-vessels which were visible microscopically and coursed transversely to the long axis of the bowel. It must have hampered the expansion of the (normally) narrow descending colon.

Although appendices epiploicæ are popularly regarded as being always "little" peritoneal processes or tags, it is very common to find enormous free folds of peritoneum (appendices epiploicæ) lying in front of the descending colon. They were present in four out of the five adults whose abdomens were dissected this term (Long Vacation, 1914). The measurements of the folds were as follows:—

	Length of Fold.	Maximum Height.
(1) . . .	10 cm.	5 cm.
(2) . . .	16 „	6 „
(3) . . .	25 „	4 „
(4) . . .	38 „	4·5 „

In (5) the only female dissected, the condition present is indicated in fig. 2.

In (4) the fold extended from the splenic flexure to the pelvic brim, and

FIG. 4.—Extensive pre-colic folds (appendices epiploicæ) removed from two adults. In the specimen to the left the colon between the splenic flexure and the pelvic brim has also been removed. It lies behind, and except at its upper part, is completely concealed by the fold between a part of which and the bowel a piece of white wax taper has been introduced. A small strip of parietal peritoneum (formerly mesocolon) has been removed with the bowel, and its endothelium is seen to be continuous with that of the fold. The appearance is very similar to that seen in adult B (fig. 3), where the fold has adhered to the colon. To the right is a still longer, but relatively narrow, appendix epiploica perforated by a foramen.

then along the pelvic colon for a considerable distance. In (2) half the fold lay along the pelvic colon. In (3) the fold extended from just below

the splenic flexure to the pelvic brim. In (1) the fold reached to the pelvic brim.

Lying in front of the descending colon, gigantic folds were also present in three of the twelve adults examined last term (May 1914). Two are shown in fig. 4. Although 25 cm. long, the fold seen to the right in the photograph did not exceed 3 cm. in height. It overlapped another large fold (12 cm. long and 3 cm. high).

In every case these folds arose from the peritoneum exactly along the inner border of the bowel, so that the endothelium of the fold was continuous with that of the parietal peritoneum (formerly ascending mesocolon) on the one hand and with that of the bowel on the other. As seen in fig. 4 it thus appeared as if the parietal peritoneum were prolonged over the colon. They all contained arteries (ultimate branches of the middle and left colic and sigmoid) visible macroscopically and lying at right angles to the long axis of the bowel. Had they become fused to the bowel a membrane exactly similar to that in adult B (see fig. 3) would have resulted.

There can be no doubt that this membrane was formed by a gigantic appendix epiploica which had become adherent to the bowel.

This adhesion may occur during fœtal life. In a fœtus 17 cm. long (see fig. 5) I found a membrane almost exactly similar to that present in adult B. It was an extensive sheet reaching from the upper end of the descending colon downwards to the ilio-pelvic colon. It had no connexion with the great omentum. It adhered to the bowel, but its left border, which came into contact with the lateral abdominal wall, was free and irregular, and here the membrane had all the characters of an ordinary fœtal appendix epiploica. It contained blood-vessels which were visible to the naked eye and coursed outwards parallel to one another (see figure). Running longitudinally as well as transversely in the membrane were also some bundles of non-medullated nerve-fibres. The membrane was loosely attached to the colon by connective tissue containing some more deeply lying vessels and nerves, some of which could be seen entering the muscular coat of the bowel. It was undoubtedly formed by a very large appendix epiploica.

The largest appendices epiploicæ which I have met with tend to spring from the colon nearest the line where the arteries first reach the bowel; and they tend to fuse to the ascending and descending colons from within outwards. In some cases the folds fuse down at some distance from their border of origin; in some cases simply at the border towards which the main arteries in the fold course.

We have seen that a pre-colic fossa and a parieto-colic fold of Jonnesco

may be formed in this way. A large and strong parieto-colic fold containing fat, and projecting from which were small appendices epiploicæ, was present in one of the adults dissected last term. It passed from the lateral part of the colon and bounded a deep retro-colic fossa. Without much doubt it had been formed in the way I have described in the fœtus.

In other cases a foramen, which might prove to be of surgical interest, results. Thus in adult B (see fig. 3) a strong appendix epiploica passed from one part to another of the transverse colon. It adhered most firmly

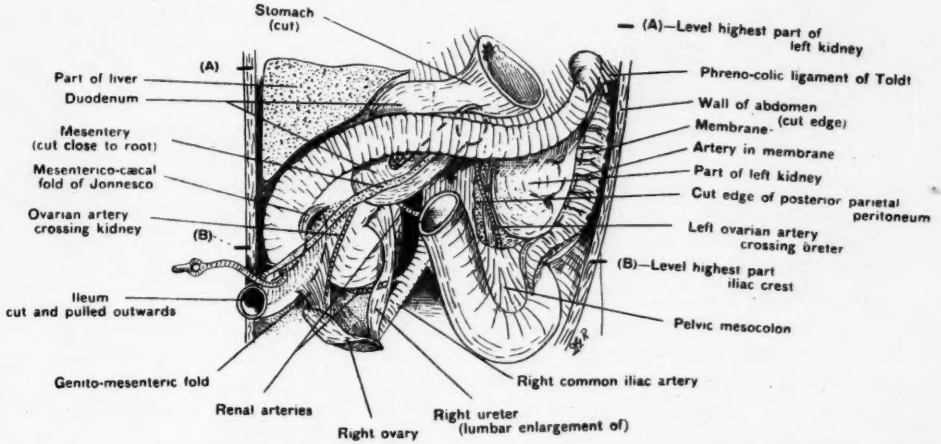

FIG. 5.—Fœtus No. II., ♀, 17 cm. long (vertex to coccyx). An extensive membrane is present in front of the descending colon. The renal ducts differ considerably in length; and the right kidney, extending from the upper border of the body of the first to the lower border of the body of the fifth lumbar vertebra, lies considerably below the left, which reaches from the upper part of the eleventh dorsal to the lower part of the third lumbar centrum (*cf.* (A), (A)). The lower part of its hilum is placed on the ventral surface of the kidney and looks directly forwards. Above the hilum passes on to the inner border of the kidney and looks inwards and forwards as in the adult. An accessory renal artery arises from the right common iliac artery and passes behind the ureter to enter the lower extremity of the right kidney. Above this two renal arteries enter the renal sinus, one at each extremity of the upper part of the hilum. They arise separately from the aorta, distinctly below the level of the normal left renal artery, and cross in front of the inferior vena cava. The lower artery, directed somewhat upwards, is retro-pelvic. The upper (horizontal) is pre-pelvic, with a strong retro-pelvic branch; and this disposition is perhaps interesting in association with the more equal development of the upper parts of the labia of the hilum (*cf.* A. H. Young and Peter Thompson, *Journal of Anatomy and Physiology*, vol. xxxviii. p. 1). The descending colon skirts the outer border of the left kidney; and its lower part curves inwards to intervene between the lower pole of the kidney and the iliac crest. (In another 17-cm. fœtus the lower pole of each kidney was 4 mm. above the crest; and in a third 17-cm. fœtus the lower pole of the *right* kidney was 8, and that of the left 3·5 mm. above the crest.) The highest and lowest points of the suprarenal glands lie at exactly the same level, but whilst the left suprarenal gland "descends" upon the anterior surface of the kidney to the highest point of the renal hilum, the right lies in contact simply with the upper pole and adjacent part of the *outer* border of the right kidney, and is not at all in front as is the case in other fœtuses of this size where the kidney lay higher. Note also the differences in the relations of the ovarian arteries to the kidneys. The ilium is quite closely bound to the right ovary and Fallopian tube by a genito-mesenteric fold of peritoneum. In relation to this fold the mesentery has been slightly lowered by adhesions (indicated by the stippling). (+ indicates a small central part of the posterior parietal peritoneum.)

to the bowel, and bounded a foramen through which I could readily thrust a loop of small intestine.

Appendices epiploicæ may join together two different parts of the large intestine. This is seen in adult A (see fig. 2). In several adults I have noted the presence of foramina in large free appendices epiploicæ.

In some cases they are bounded by a thin edge, immediately around which the fold contains little or no fat, and have the appearance of having been produced by absorption. In other cases they may quite well be formed by the fusion together of two parts of the same fold (see fig. 4) or of two separate appendices epiploicæ. But it is noteworthy that in no specimen did they interrupt the line of origin of the fold, although they sometimes lie quite close to the attached border; and I have not as yet seen them in the fœtus.

Fig. 6 indicates an ordinary type of colon and its relations to parietal structures. In adult B (fig. 3) the terminal part of the ileum was fixed to the parietal peritoneum by what was probably a very small remnant of the genito-mesenteric fold; and between this fold and the ileo-cæcal junction seemed as it were to have become too long to lie in a straight line. At all events, although not actually kinked, it formed a curve convex upwards.

Fig. 3 and fig. 8 of my paper in the *Proceedings of the Royal Society of Medicine*, February 1914, indicate very clearly one of the ways in which an acute and permanent flexure of the terminal part of the ileum may be produced. The two ends of a fixed portion of this are in some cases approximated if the cæcum be able to complete its descent.

In adult A (see fig. 2) the colon had undergone considerable modifications. By the great omentum the right part of the transverse colon was closely and firmly bound to the ascending colon downwards to a point $\frac{3}{4}$ inch from the ileo-cæcal junction. The transverse colon then passed to the left and then downwards to reach the iliac colon, to which it was firmly bound by an appendix epiploica, at a point 1 inch from the external iliac artery. It then ascended to a normally placed splenic flexure. In this part of its course it lay directly in front of the iliac and descending colons, no small intestine intervening, as of course is normally the case. The descending colon was completely hidden behind it. In the upper $1\frac{1}{2}$ inch of its course adhesions bound it directly to the anterior surface of the descending colon.

A distinct ascending mesocolon, when it exists, is often formed very largely through stretching of the mesentery during the descent of the cæcum. For this reason flexures when found upon the ascending colon are usually of the nature shown in fig. 1, and usually temporary. On the other

hand, I have often found the sub-splenic loop (see fig. 7) upon the upper part of the descending colon, and have always seen it as a permanent loop. It occurs in the fœtus and adult, and is always antero-posterior in direction.

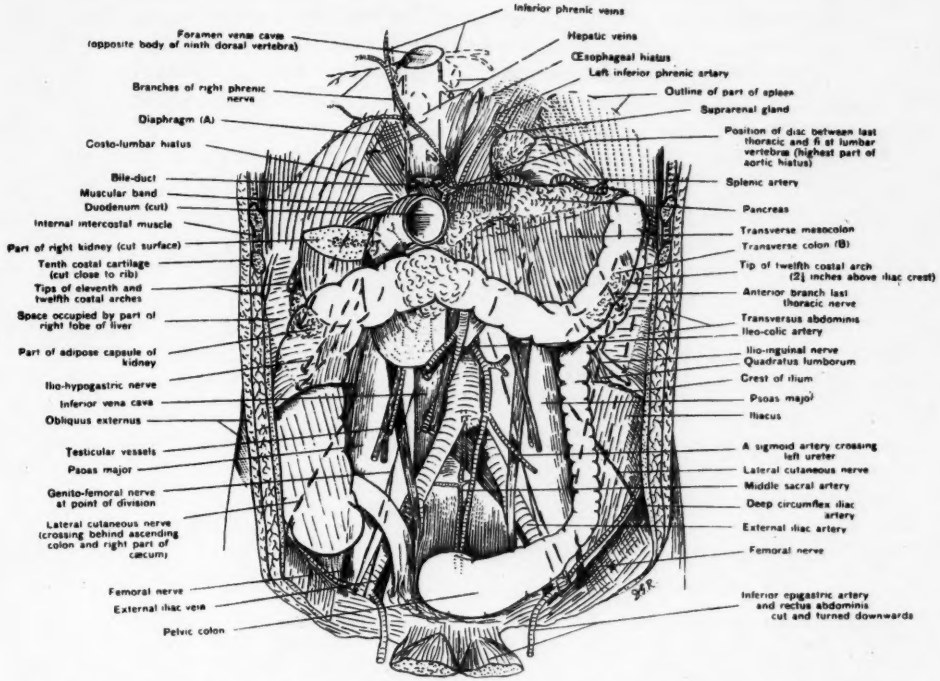
Inferior phrenic veins
Foramen venæ cavæ (opposite body of ninth dorsal vertebra)
Hepatic veins
Œsophageal hiatus
Left inferior phrenic artery
Branches of right phrenic nerve
Outline of part of spleen
Suprarenal gland
Diaphragm (A)
Position of iliac between last thoracic and 1st lumbar vertebræ (highest part of aortic hiatus)
Costo-lumbar hiatus
Bile-duct
Muscular band
Duodenum (cut)
Splenic artery
Pancreas
Internal intercostal muscle
Transverse mesocolon
Part of right kidney (cut surface)
Transverse colon (B)
Tenth costal cartilage (cut close to rib)
Tip of twelfth costal arch (2¼ inches above iliac crest)
Tips of eleventh and twelfth costal arches
Anterior branch last thoracic nerve
Space occupied by part of right lobe of liver
Transversus abdominis
Ileo-colic artery
Part of adipose capsule of kidney
Ilio-inguinal nerve
Quadratus lumborum
Ilio-hypogastric nerve
Crest of ilium
Inferior vena cava
Psoas major
Obliquus externus
Iliacus
Testicular vessels
A sigmoid artery crossing left ureter
Psoas major
Lateral cutaneous nerve
Genito-femoral nerve at point of division
Middle sacral artery
Deep circumflex iliac artery
Lateral cutaneous nerve (crossing behind ascending colon and right part of cæcum)
External iliac artery
Femoral nerve
Femoral nerve
Inferior epigastric artery and rectus abdominis cut and turned downwards
External iliac vein
Pelvic colon

FIG. 6.—Adult. The posterior relations of an ordinary type of colon are indicated. The anterior branch of the last thoracic nerve pierces the tendon of transversus abdominis 1 to 1½ inches above the crest of the ilium and ·5 to 2 cm. external to the outer border of quadratus lumborum. On the right side it is separated from the upper end of the ascending colon by the kidney and its adipose capsule. The nerve also lies behind the descending colon, but is separated from this by the part of the adipose capsule which is wedged into the dihedral angle between the lateral border of the kidney and the tendon of transversus abdominis. The transverse colon at (B) is, of course, normally separated from the descending colon by coils of small intestine (*cf.* adult B, fig. 3). The two chief variations in the course of the descending and iliac colons are indicated by continuous and interrupted lines. At (A) there is a decussation of the costal and lumbar parts of the diaphragm, the former passing in front of the latter. The "muscular band" lies parallel to the lateral lumbo-costal arch. It passes from the medial lumbo-costal arch to join the costal fasciculi of the diaphragm. It is absent on the left side where the fasciculi which usually arise from the lateral lumbo-costal arch are completely absent and there is a large costo-lumbar hiatus. The muscular fasciculi which bound the œsophageal hiatus come entirely from the right side, the deeper (more posterior) fibres passing to the left, and the more anterior to the right of the œsophagus. As in the fœtus the ileo-colic artery arises from the superior mesenteric vessel as this is crossing the third part of the duodenum. Primitively it always courses along the root of the mesentery. The descending and iliac colons are very narrow. The latter inclines slightly outwards. Students at the stage when they remove the large intestine are recommended to make a careful dissection to expose the parts which lie behind the ascending and descending portions of the colon. The trigonum lumbale (Petiti) should also be dissected from the front as well as from behind.

It is an acute flexure, and is permanent owing to the firm fusion together of its limbs and the loss of its mesentery. Sometimes it also adheres to the lateral parietal peritoneum, with which it lies in contact.

In fœtus No. 1 (fig. 1) another antero-posterior loop is seen upon the lower part of the descending colon just above the crest of the ilium. But it had a mesentery, continuous with that of the ilio-pelvic colon, and was therefore not a permanent flexure. The sub-splenic loop is, without much doubt, also formed whilst the upper part of the descending colon is still free.

FIG. 7.—Fœtus No. 3, ♂, full-time. Viewed somewhat from the left side. The sub-splenic loop lies between two strips of white paper. It is really antero-posterior in direction and lay in contact with the lateral abdominal wall (turned back) to which it did not adhere. A broad strip of white paper has been placed above the *left colic loop*, which forms a very acute flexure. Another strip of white paper indicates the fold of transverse mesocolon below the right limb of the loop.

In the fœtus, as in the adult, the descending colon may curve inwards in relation to the lower extremity of the kidney and then closely skirt the outer border of the psoas (see fig. 5). In many other cases (see figs. 2, 3, and 6) it descends without so curving inwards, and along with the upper part of the iliac colon forms with the lateral border of psoas an angle of variable size. In some cases it is the pelvic colon which prevents this curve.

In other cases the pelvic colon lies to some extent in front and in other cases even partly lateral to the lower end of the descending colon. We have now indicated in the fœtus most of the modifications which the pelvic colon may produce in the peritoneum and in the position, form, or direction

of viscera (including of course the genital gland, and especially the left ovary and Fallopian tube). (Other points regarding the relations of the colon, etc., are shown in fig. 6.) Fig. 7 also indicates how in the case of the transverse colon the left colic loop of Jonnesco may come to form an acute flexure. The fold (containing two arteries, one along its free border) of transverse mesocolon is seen which has resulted from the movement of the right limb upwards and to the left towards the left limb of the loop.

For other variations in the form of the intestines see my papers in the *Journal of Anatomy and Physiology*, the *Proceedings of the Royal Society of Medicine*, February 1914, and the *Transactions of the Medico-Chirurgical Society of Edinburgh*, 1913–14.

The retro-pancreatico-duodenal fossa was present, well marked, in one of the adults dissected last term (May 1914). It descended beyond the first portion of the duodenum and behind the upper part of the head of the pancreas; but the caudate lobe (process) of the liver did not descend to separate its anterior and posterior walls from contact with one another.[1]

An "intermediate" retro-duodenal fossa, 8 cm. long, was present in another adult. Its orifice lay immediately behind the highest part of the left border of the fourth portion of the duodenum, and was just large enough to admit the little finger. The fossa descended behind the left part of the posterior surface of the fourth portion, and then along the lower border of the third portion, of the duodenum. It terminated at the right border of the aorta, opposite the superior mesenteric vein, in the interval between the superior mesenteric artery and its ileo-colic branch (see fig. 6). I have already figured a very similar fossa in the adult.

[1] I must here refer to C. M. Jackson's paper "On the Topography of the Pancreas in the Human Fœtus," *Anatomischer Anzeiger*, Band xxvii., 1905. I regret that at the time I wrote on the duodenum this interesting paper had escaped my notice.

THE TOPOGRAPHICAL AND APPLIED ANATOMY OF THE GALL-BLADDER AND BILE-DUCTS.

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(Read at the Glasgow Meeting of the Anatomical Society, June 1914.)

In most text-books of anatomy the gall-bladder and extra-hepatic bile-ducts are only very briefly described. The large and increasing number of operations now being performed on the biliary apparatus would seem to render unnecessary any excuse for the more detailed description given here.

In order to determine exactly the topographical anatomy of the gall-bladder and ducts, thirty-one subjects were carefully examined. Of these, twenty-three were ordinary dissecting-room bodies, in which special dissections were made. Five were bodies which had been frozen and sectioned, four in transverse and one in sagittal planes, by Professor Symington, the late Professor Dickey, and Mr P. T. Crymble.

Reconstructions displaying the biliary apparatus, adjacent organs, ribs, etc., from the front were made in all five; and in two, separate reconstructions were made, showing the same organs from the right side. Three fœtuses were also studied.

The examination of this material showed that the usual description of the bile-ducts is very inadequate, and emphasised the importance of studying anatomy, not only by ordinary dissection, but also by means of serial sections. Reconstructions made from such sections furnish by far the most accurate method of determining the position and relations of organs, or the course of such a structure as the common bile-duct.

I am unable to find in English text-books of anatomy any reference to the marked bend in the course of the common bile-duct, or to the fact that the middle division of the duct, which includes the bend, is firmly fixed, while the positions of the first and third divisions are easily influenced by movements of related viscera.

I think it best to describe the ordinary anatomy of the gall-bladder, cystic, common hepatic, and common bile-ducts in the above order, and then in the same order their applied anatomy.

The diagrams (figs. 1 and 2) represent the normal relations of the gall-bladder and ducts viewed from the front and right side respectively. For the sake of clearness the portal vein was omitted, and no attempt made to depict the liver.

The Gall-bladder.

The gall-bladder, pyriform in shape, lies in a fossa on the inferior surface of the right lobe of the liver. For descriptive purposes it is divided into three parts—the fundus, the body, and the neck, which is continuous with the cystic duct. It is directed obliquely from before backwards and medially, so that the fundus, which is the most anterior part, lies at a lower level and further from the middle line than the neck (fig. 1).

With the exception of the superior surface of the body, which is

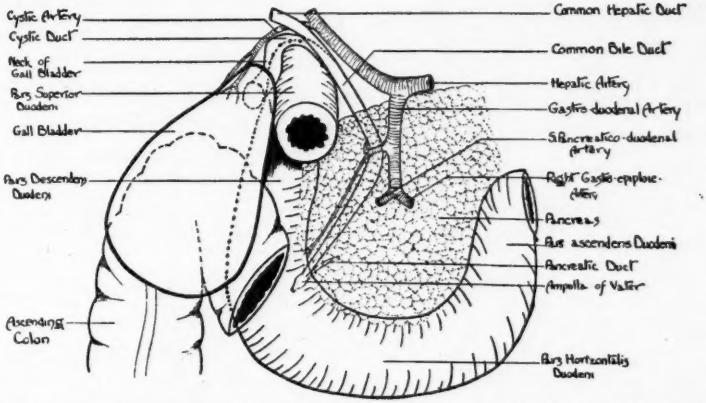


Fig. 1.—Diagram showing the relations of the gall-bladder and extra-hepatic bile-ducts viewed from the front. The artery hooking round the bend (slightly exaggerated) in the course of the common bile-duct is not labelled. The line indicating the neck of the gall-bladder also indicates the position of the cystic gland.

attached to the liver by areolar tissue, the gall-bladder is covered by peritoneum. In some cases, however, the peritoneum surrounds it completely and forms a short mesentery, attaching it to the liver.

Relations.

The Fundus.—Completely covered by peritoneum, the fundus usually projects beyond the sharp margin of the liver and lies in contact with the anterior abdominal wall, about the junction of the transpyloric and right lateral planes. Below, it rests on the right colic flexure and the first part of the transverse colon.

The Body.—The superior surface of the body is attached to the liver by areolar tissue and some small veins, the other surfaces being covered by

peritoneum. The infero-lateral surface is related to the right colic flexure, and the infero-medial to the superior and descending parts of the duodenum (figs. 1 and 2).

The Neck.—The neck, beginning below the highest point of the body, curves upwards and forwards, and then, bending suddenly backwards and downwards, becomes continuous with the cystic duct (fig. 2). It is covered by peritoneum, except on its anterior and superior surfaces. The anterior surface is in contact with the body of the gall-bladder, and the superior surface connected with the liver by loose areolar tissue through which passes the cystic artery and in which lies frequently a small lymphatic gland.

Inferiorly it is related to the first part of the duodenum.

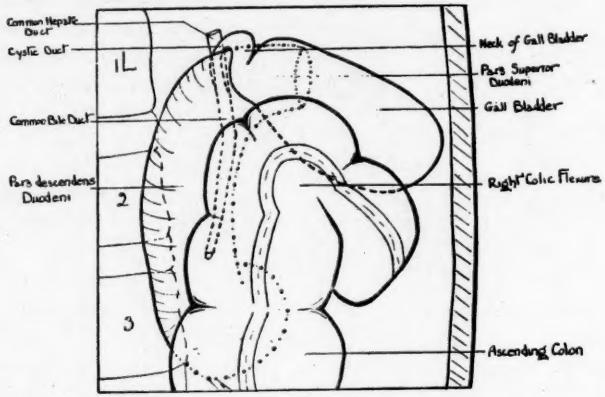


FIG. 2.—Diagram showing the relations of the gall-bladder and extra-hepatic bile-ducts viewed from the right side. Note the bend concave posteriorly of the common bile-duct. 1 L, 2, 3, bodies of first three lumbar vertebræ.

The Cystic Duct.—Lying in the highest part of the free margin of the gastro-hepatic omentum, the cystic duct passes downwards, backwards, and medially over the first part of the duodenum. It runs for a short distance parallel with and adherent to the postero-lateral aspect of the common hepatic duct before joining it to form the common bile-duct (figs. 1 and 2). The cystic artery courses to the gall-bladder along the antero-superior aspect of the duct; the portal vein lies behind, the hepatic artery to the left.

The external appearance of the cystic duct gives little or no indication of the size of its lumen owing to the presence of folds of mucous membrane, which, arranged in a spiral manner, project into the channel and render it

small and tortuous. These folds constitute the spiral valve of Heister, and into their structure enter, not only mucous membrane, but also non-striped muscle (continuous with the circular fibres of the duct (1)) and a framework of connective tissue.

The Common Hepatic Duct.

The right and left hepatic ducts unite in the transverse fissure of the liver to form the common hepatic duct. This duct, running medially downwards in the gastro-hepatic omentum lateral to the hepatic artery, and in front of the portal vein and cystic artery, joins the cystic duct to form the common bile-duct.

The Common Bile-duct.

The peculiar course of the common bile-duct, its varying relations at different levels, and the different routes by which the surgeon gains access to it, render its description in three stages advisable.

Charpy (2) describes three portions—a superior or duodenal, a middle or pancreatic, and an inferior or intra-parietal. This is the best method of subdividing the duct; but since the inferior part is more intimately related to the duodenum than the superior, I think it better named duodenal, while the superior may be called supra-pancreatic.

The Superior or Supra-pancreatic Division.—Formed at the level of the first lumbar vertebra (figs. 1 and 2) by the junction of the cystic and common hepatic ducts, the supra-pancreatic portion of the common bile-duct proceeds downwards, backwards, and medially to the upper border of the head of the pancreas. It lies in the free edge of the gastro-hepatic omentum with a few lymphatic glands around it; the portal vein lying behind, the duodenum lateral, and the hepatic artery medial.

The Pancreatic or Middle Division. — Continuing for a variable distance in the same direction as the superior part, the pancreatic division then bends to the right, passes downwards, backwards, and laterally, and, accompanied in its terminal few millimetres by the main pancreatic duct, reaches the postero-medial aspect of the descending part of the duodenum. It lies either in a groove on the posterior surface of the head of the pancreas, or in a canal in its substance. In the former position it is merely separated from the inferior vena cava by some connective tissue. The gastro-duodenal artery, lying on an anterior plane, gives off a large branch which passes backwards through the head of the pancreas, and, having reached the common bile-duct at the level of the bend, divides; one branch, hooking round the duct, gives twigs to it and the pancreas;

the other, coursing along the lateral aspect of the duct, reaches the duodenum.

A number of large sympathetic nerve fibres pass to the median aspect of the duct. These course either in the substance of the pancreas or along its posterior surface. They are not accompanied by blood-vessels.

The Inferior or Duodenal Division.—Accompanied by the pancreatic duct, the inferior division of the common bile-duct pierces very obliquely the walls of the descending part of the duodenum. Both ducts terminate by opening into a common dilatation, known as the ampulla of Vater, which communicates with the lumen of the duodenum through a minute orifice situated on the apex of a small papilla.

In short, then, the complete course of the common bile-duct is as follows:—From its origin, it first passes downwards to the left and slightly forwards as far as the hooking artery in the pancreatic substance. From this to its opening into the duodenum it passes downwards to the right and slightly backwards. Thus it displays a double curvature; the more pronounced having its convexity directed to the left, the other having its convexity forwards (figs. 1 and 2).

Blood-supply.—The cystic artery (fig. 1), which is a branch of either the hepatic or its right division, passes behind the common hepatic duct and, coursing along the antero-superior aspect of the cystic duct, reaches the gall-bladder. It then divides; the superior branch supplying the upper surface, the inferior the lower. The veins enter the portal system, some on the superior surface of the gall-bladder piercing the liver.

The common bile-duct is supplied by a branch of the gastro-duodenal artery, and at its terminal part by the superior pancreatico-duodenal artery.

Lymphatics.—Practically all the lymph from the gall-bladder drains into the cystic gland, and from it through a series of glands arranged along the course of the bile-ducts. Efferent vessels from these communicate with the pancreatic glands.

Nerve-supply.—The gall-bladder is supplied by branches of the vagi nerves and sympathetic fibres from the cœliac plexus. The segments from which the sympathetic fibres arise are the 7, 8, 9, 10 thoracic (3).

Applied Anatomy.

Gall-bladder.—The gall-bladder is related to the sub-hepatic region (right sub-phrenic intra-peritoneal space) of the greater peritoneal sac. Gall-stones may, therefore, enter this sac, or a general peritonitis result from perforation (fig. 3).

A right, sub-phrenic, intra-peritoneal abscess not infrequently occurs

with cholecystitis; and the relations of the peritoneum show that if adhesions are present in certain localities, pus may be readily limited to this area. The abscess cavity is bounded above by the peritoneum, covering the under surface of the right lobe of the liver, and by the coronary and right lateral ligaments; in front and below by the transverse colon,

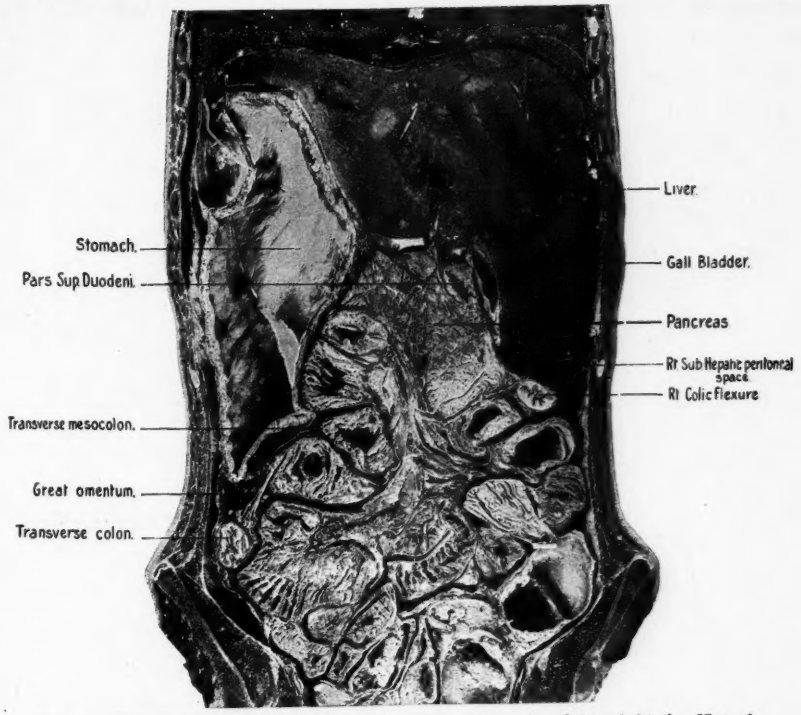


FIG. 3.—Photograph of a coronal section of a male aged 12, viewed from behind. Note the relation of gall-bladder to the pancreas, duodenum, and the sub-hepatic peritoneal space.

adherent to the liver and anterior abdominal wall, or by a fold of great omentum (fig. 12) adherent to the liver and colon; laterally by the peritoneum on the lateral abdominal wall; and medially by duodenum and by adhesions closing the foramen of Winslow.

With the liver in normal position, the neck of a distended gall-bladder projects upwards and medially between the layers of the gastro-hepatic omentum (fig. 4), thus admitting the possibility of gall-stones entering the lesser sac, or of suppuration involving either the portal vein or hepatic

artery. The superior surface of the gall-bladder being devoid of peritoneum (fig. 3), a suppurative cholecystitis may directly infect the liver, and give rise to a localised abscess continuous with the cavity of the gall-bladder (4), or multiple abscesses be caused by infection spreading along the small veins which pass from the gall-bladder through the liver and communicate with the portal system.

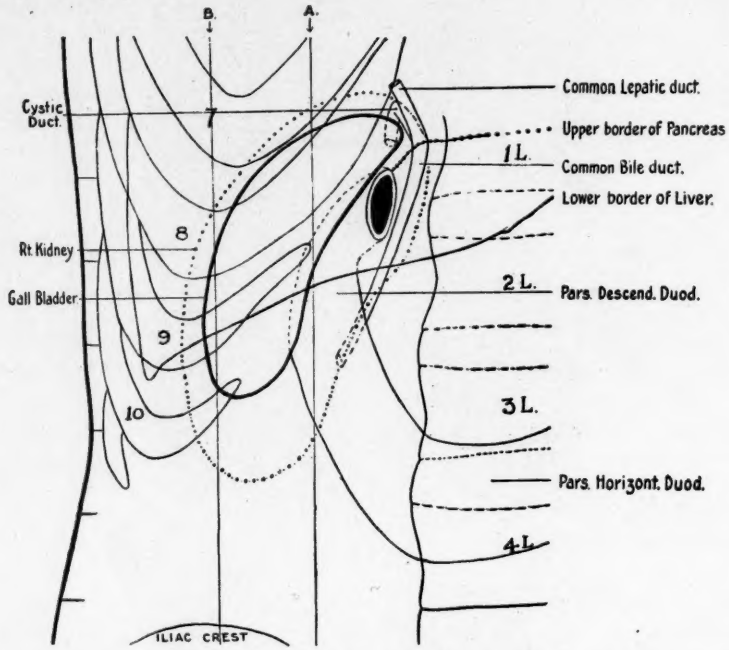
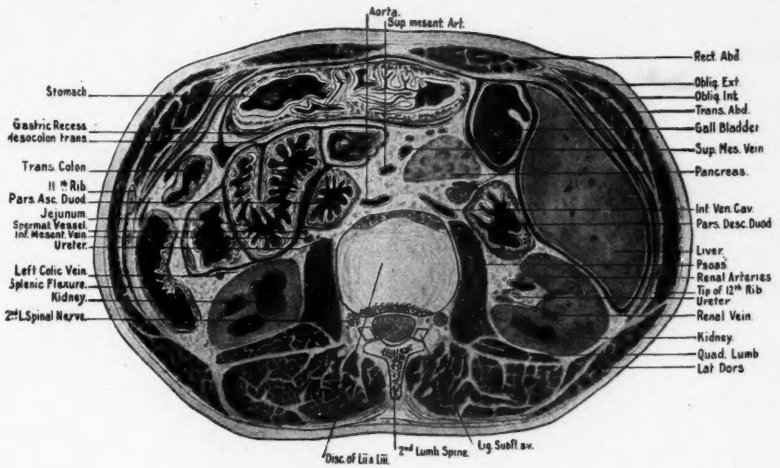


FIG. 4.—Reconstruction from a series of sagittal sections of a man aged 40, viewed from the front. Figs. 6 and 7 are drawings of two of these sections, indicated on this figure by the lines B and A respectively. Note the distended gall-bladder and the adherence of the entire cystic duct to the common hepatic duct. It will be seen that there is no supra-pancreatic division of the common bile-duct. ½ natural size.

In those subjects in whom the gall-bladder is suspended from the liver by a mesentery, a distended gall-bladder forms an abdominal tumour freely movable from side to side; and cases have been reported in which a localised abscess was present between the layers of this mesentery.

Enlargement of the cystic gland may cause obstruction, or the diseased gland may become adherent to the neck of the gall-bladder, and be mistaken for a gall-stone (fig. 1).

In every subject examined the gall-bladder was related to the duodenum and colon; the duodenum being related to the neck and part of the body; the colon to the body, the fundus, and occasionally to the neck (fig. 14). These relations account for the fact that gall-stones, ulcerating into the alimentary canal, usually enter either by the duodenum or the colon, but more frequently by the former. The constant relation of the duodenum to the neck of the gall-bladder, in which stones are often impacted, and its relatively fixed position, account for the more frequent involvement of the duodenum.



SECTION 13.

FIG. 5.—Transverse section at the level of the disc between the 2nd and 3rd lumbar vertebræ; man aged 50. Note relation of the gall-bladder to the anterior abdominal wall, stomach, pancreas, and the duodenum. The level of this section is indicated by the number 13 on the left side of fig. 8. ⅓ natural size.

The gall-bladder is often related to the pylorus, and in three cases was in contact not only with the pylorus, but also with the body of the stomach (fig. 5). Naunyn (5) quotes eight cases of fistula between stomach and gall-bladder.

In two cases a portion of the ileum was only separated from the fundus of the gall-bladder by the transverse mesocolon; in a third, two loops lay in contact with it (fig. 6). This relationship is unusual, but may occur if the large intestine is fixed in an abnormal position, or in cases of great distension of organs, such as the stomach, the descending colon, the bladder, or the rectum (6). Naunyn reports two cases of fistulæ—one between the gall-bladder and ileum, the other between the gall-bladder and the jejunum.

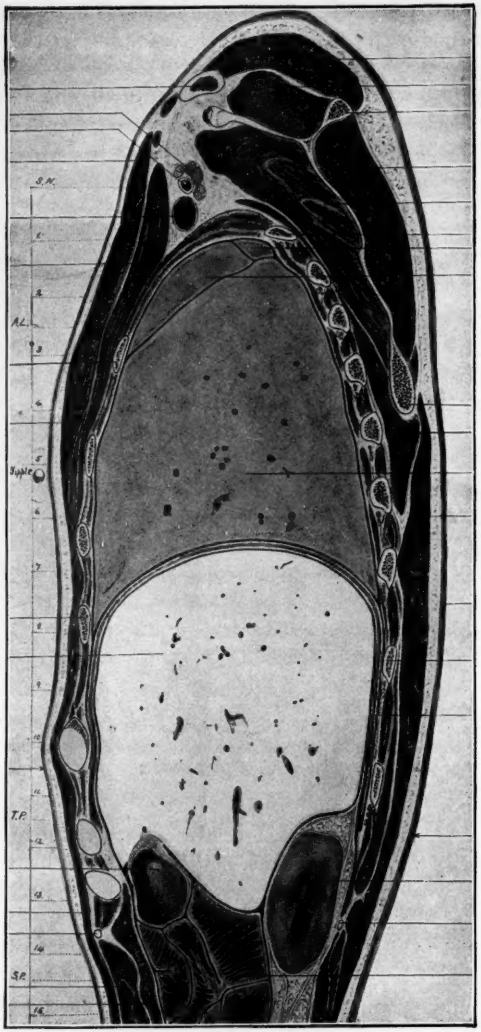


FIG. 6.—Sagittal section, line B, fig. 4, viewed from medial side. Note relation of gall-bladder to anterior abdominal wall and small intestine.

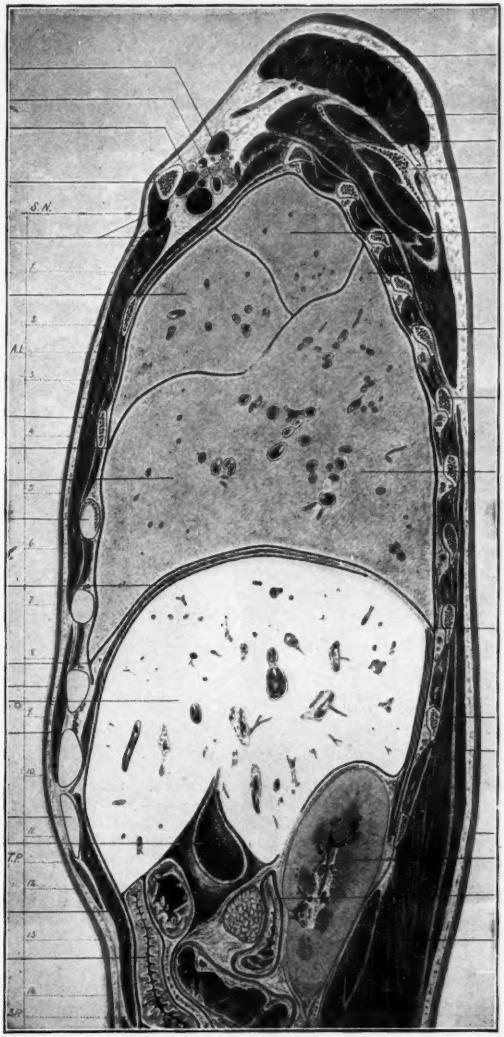


FIG. 7.—Sagittal section, line A, fig. 4, viewed from medial side. Note the proximity of gall-bladder to kidney, and that small intestine lies above and in front of the colon.

The gall-bladder was not in contact with the kidney in any of the bodies examined; but their close proximity is seen in fig. 7. Courvoisier (7) reported five cases of a fistulous opening between the gall-bladder and the pelvis of the right kidney.

In one subject the gall-bladder was related to the cæcum.

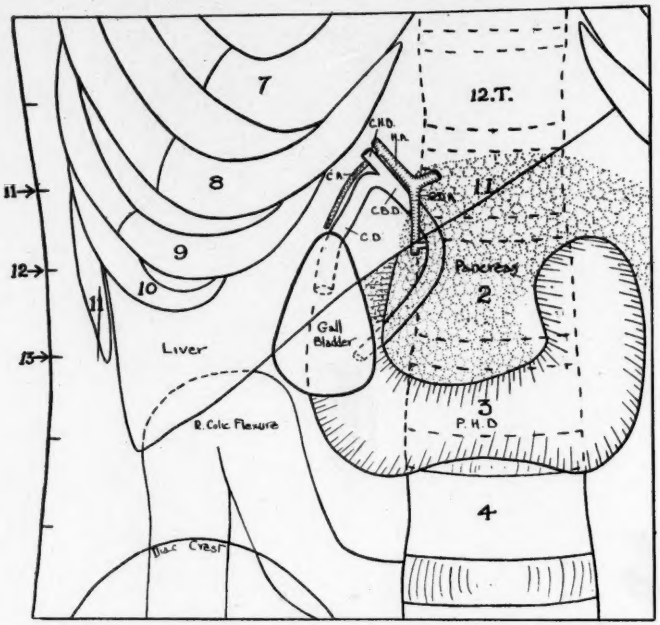


FIG. 8.—Reconstruction from a series of transverse sections of a man aged 50. Figs. 5 and 13 are drawings of the upper surfaces of two of these sections and are indicated on the reconstruction by the numbers 13 and 12 respectively. In this subject the liver was displaced downwards and anteverted. Note the marked bending of the common bile-duct. ½ natural size.

In subjects with an enlarged or anteverted liver the body of the gall-bladder is often related to the head of the pancreas (figs. 3, 5, 13), which may, therefore, be directly infected during the course of a cholecystitis.

External biliary fistulæ may open anywhere on the right half of the abdominal wall, usually about the umbilicus, the pus, it is supposed, being directed towards this region by the falciform ligament; but it may also be accounted for by the fact that, in downward displacement of the liver, the fundus of the gall-bladder comes into contact with this region of the abdominal wall.

The gall-bladder fixed to the liver necessarily follows its movements, normal and abnormal. Downward displacement with anteversion rotates the fundus of the gall-bladder downwards and medially, so that it lies as near the middle line as the neck, or even nearer (fig. 8), and comes into contact with the pancreas, the pylorus, and sometimes with the body of the stomach (figs. 3, 5, 13).

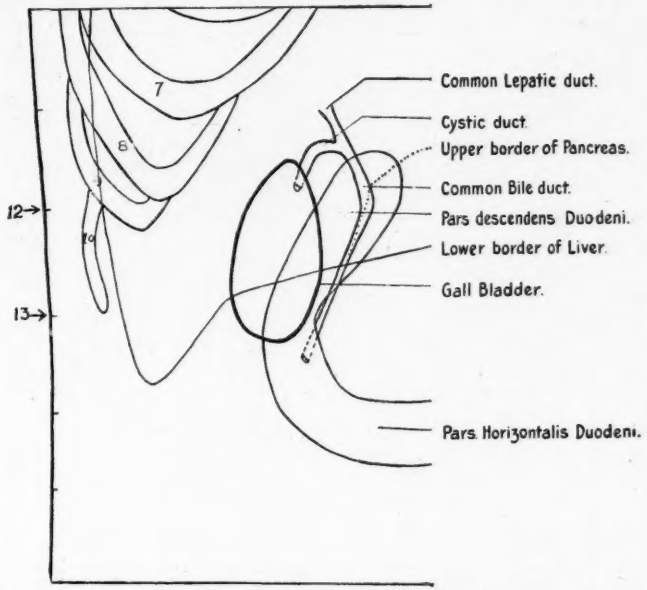


FIG. 9.—Reconstruction from a series of transverse sections of a girl aged 14. Fig. 11 is a drawing of the upper surface of the section labelled 13 on the reconstruction. Liver enlarged but not displaced; its upper surface reached the normal level. ½ natural size.

The same condition may also result from simple enlargement of the liver (fig. 9).

Upward displacement with retroversion produces an outward and upward rotation of the fundus, so that it may lie in the mid-axillary line (fig. 10).

In three of the cases examined the fundus lay under the ninth rib in this line. Of these all had small livers, two had greatly distended stomachs, and in one there was a very large left pleural effusion.

The important bearing which these movements have on the course and relations of the bile-ducts will be described later.

The gall-bladder may not be in contact with the abdominal wall (fig. 11); thus, in some of the cases examined the anterior margin of the liver intervened, in one the transverse colon, in one the cæcum, and in several a fold of great omentum.

Cystic Duct.—In many cases it is extremely difficult to determine the junction of the neck of the gall-bladder with the cystic duct, especially when displacement of the liver exists (figs. 10 and 12). If a surgeon

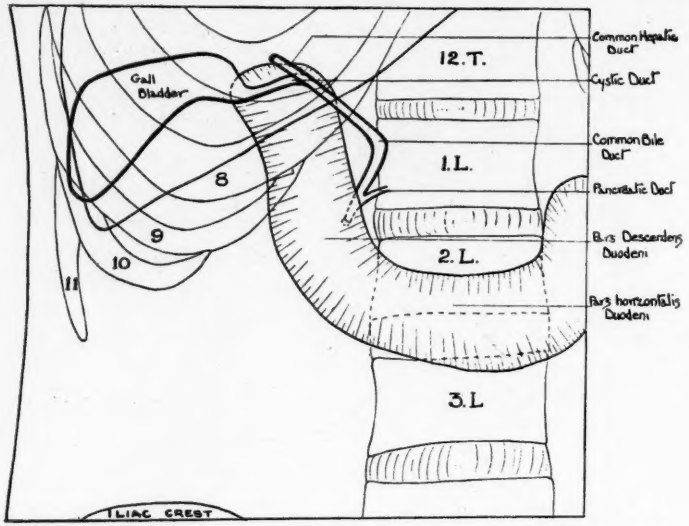


FIG. 10.—Reconstruction from a series of transverse sections of a man aged 68. The fundus of the gall-bladder is related to abdominal wall in the mid-axillary line. Neck of the gall-bladder and cystic duct pass transversely inwards. The pars superior and pars descendens duodeni are displaced laterally. Marked bending of the common bile-duct. This reconstruction demonstrates the fixation of the pancreatic division of the common bile-duct, for notwithstanding the outward displacement of the gall-bladder and duodenum it has retained its normal position. ½ natural size.

performing a cholecystectomy fails to recognise the junction and does not completely remove the neck, then a miniature gall-bladder remains in which stones may form (8). In these cases, however, the cystic duct is not adherent to the common hepatic duct, or only for a very short distance; hence its terminal portion is easily recognised.

Outward and upward displacement of the gall-bladder straightens out the neck and cystic duct, so that they run transversely towards the middle line (fig. 10), a condition which favours the passage of fluids from the gall-bladder into the common bile-duct. Traction of the liver in an upward

and outward direction may therefore facilitate the passage of a probe through the cystic duct, an operation which, judging from the structure of the duct, one would not think likely to succeed without serious injury to the spiral valve.

The adherence of the terminal part of the cystic duct to the common hepatic duct is of supreme surgical importance. Numerous cases have been reported in which the latter was injured during operation (9), or mistaken for the cystic duct and ligatured. These accidents are most likely to occur when the gall-bladder is distended and the liver in normal

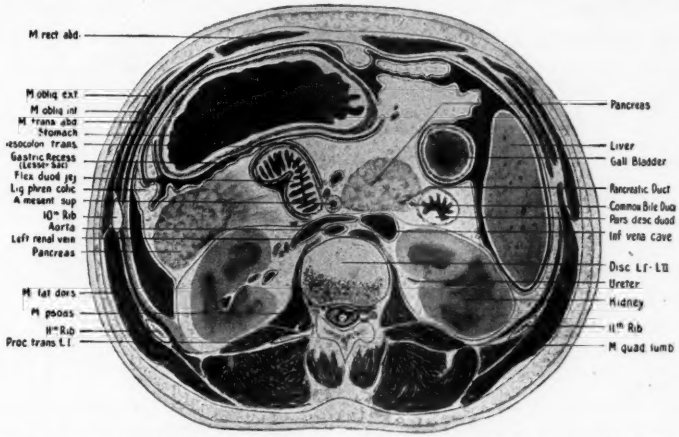


FIG. 11.—Transverse section of a girl aged 14 at the level of the disc between the 1st and 2nd lumbar vertebræ. Note the relation of the fundus of the gall-bladder to the sub-hepatic peritoneal space, to the pancreas, and to the duodenum, and that it is separated from the abdominal wall by a fold of great omentum. The common bile-duct lies in a groove on the post-surface of the head of the pancreas and could easily be reached by turning forwards the duodenum. The level of this section is indicated on fig. 9 by the number 13. $\frac{1}{3}$ natural size.

position, because the neck projects medially upwards between the layers of the gastro-hepatic omentum and lies in contact with the common hepatic duct, the entire cystic duct being adherent to the latter (fig. 4).

Practically all forms of liver displacement tend to straighten out the cystic duct, but, as will be shown later, marked ptosis may produce a very acute bend in the cystic duct near its junction with the common hepatic duct, thus favouring obstruction at this point.

According to Professor Keith (10), the function of the spiral valve is to maintain the patency of the cystic duct; but since the folds forming this valve contain muscular fibres, continuous not only with those of the circular coat of the duct (11), but also, to a lesser extent, with those of

the longitudinal coat, one must assume that it has the power either to diminish or increase the size of the lumen. The position of the cystic artery is very constant. It may, however, pass in front of instead of behind the common hepatic duct.

The Supra-pancreatic Division.—This division of the duct, deeply situated above and behind the sharp margin of the liver and ribs, is difficult to reach for surgical purposes. Upward displacement of the liver, with retroversion, renders it more accessible (fig. 14).

The lower part of its posterior surface is often devoid of peritoneum, and is separated from the inferior vena cava by some lymphatic glands. These glands may be diseased and closely simulate gall-stones.

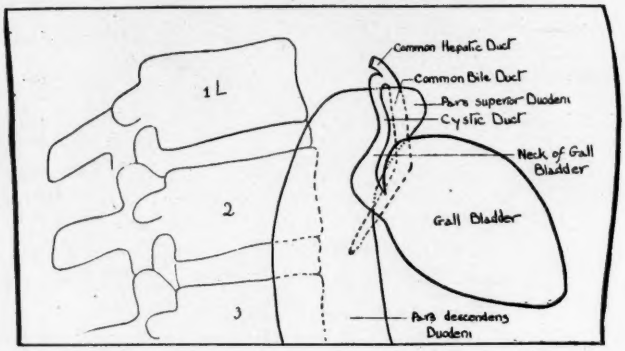


FIG. 12.—Reconstruction from a series of transverse sections of a man aged 50, viewed from the right side. Note that the cystic duct passes upwards and joins the common hepatic duct at an acute angle 1 L, 2, 3, bodies of first three lumbar vertebræ. ½ natural size.

In a small percentage of subjects the right hepatic artery is a branch of the superior mesenteric and courses upwards in close relation to the duct, sometimes lying in front of it, or even lateral to it. In the latter position it may readily be injured during operation.

Fistulæ between the duct and the duodenum, or even the stomach, may occur. Naunyn (5) collected fifteen cases of the former condition, and cases of the latter have also been recorded (4).

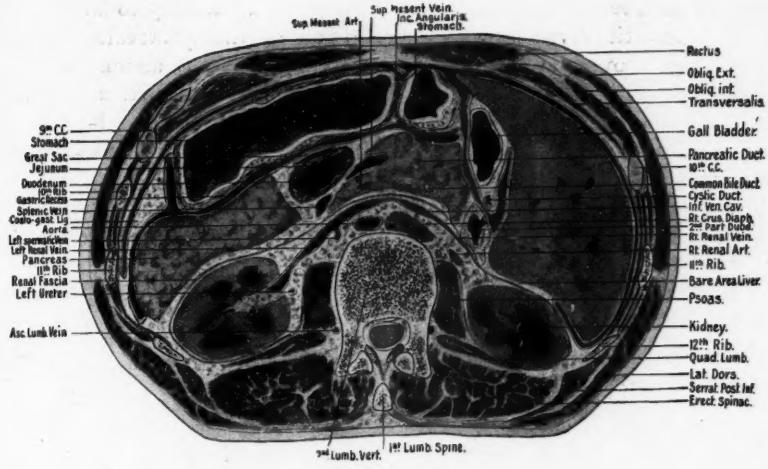
The majority of the nerve fibres passing to the liver lie median to the duct. Many, however, pass up in close relation to it. Crile (8) thinks that the high mortality rate in common-duct operations is due to injury of these nerves, and lays great stress on gentle manipulation, infiltration of the tissues with novocaine, and sharp dissection as a means of reducing the mortality.

Pancreatic Division.—The varying relations of the pancreatic division

of the duct to the head of the pancreas are of surgical importance (figs. 11 and 13).

It is usually located by cutting the peritoneum binding the pars descendens duodeni to the posterior abdominal wall and pulling this viscus forwards and to the left.

In all cases it is best to begin at the lower part of the duodenum and work upwards, because the terminal few centimetres of the duct are easily



SECTION 12.

FIG. 13.—Transverse section at the level of the 2nd lumbar vertebra. Man aged 50. Note the position of the common bile-duct; it lies in a canal in the substance of the pancreas, at a considerable distance from the duodenum, and would be difficult to reach for surgical purposes (compare with fig. 11). The level of this section is indicated on fig. 8 by the number 12. ½ natural size.

located, whereas the remainder may be embedded in the head of the pancreas (compare figs. 11 and 13). In performing the operation care must be taken of the artery (often large) which courses along the lateral aspect of the duct. Hæmorrhage, serious and difficult to control, may result from injury to this vessel.

The Duodenal Division.—Gall-stones frequently become impacted in the ampulla of Vater, and obstruct not only the flow of bile but also the pancreatic secretion. They are removed by transduodenal choledochotomy.

Effects of Liver Displacements on the Extra-hepatic Bile-ducts.—The displacements of the liver that I would specially draw attention to are the

upward displacement with retroversion, and the downward displacement with anteversion.

In the former condition, the axis of rotation having a direction downwards, forwards, and to the right, the fundus of the gall-bladder is carried outwards and upwards, and the cystic duct—the termination of which lies nearer the centre of rotation and is more or less fixed by the gastro-hepatic omentum and by sympathetic and vagal nerve fibres—necessarily straightens out, without much tendency towards kinking. The common bile-duct, however, as a result of this rotation, has a decided tendency to kink. The supra-pancreatic division, and that portion of the pancreatic division which lies above the hooking artery, straighten out, assume a more horizontal position, and are under a certain degree of tension; thus rendering more acute the bend in the pancreatic division. In cases such as fig. 10, where the duodenum is also involved in the displacement, this bend becomes still more acute as the duodenal division of the common bile-duct and that portion of the pancreatic division which lie distal to the hooking artery rotate upwards and laterally, with the hooking artery as the centre of rotation.

In downwards displacement, with anteversion, the fundus of the gall-bladder moves through a large arc downwards and medially. The cystic duct again, lying nearer the centre of rotation, moves in the same direction, but in a smaller arc, and having its termination somewhat fixed, tends, as before, to straighten out, coursing, however, not in a horizontal but in an upward and medial direction.

A further effect of this traction is that the areolar tissue binding the cystic duct to the common hepatic duct is gradually stretched and the cystic duct drawn away, leaving in some cases merely a small portion at the very termination still adherent to the common hepatic duct. It is at this point that a kink may result, causing obstruction. The cystic duct having been straightened out, traction produced by any further displacement of the liver then acts on that portion of the common bile-duct proximal to the bend, rendering it more acute, and thus producing a condition likely to cause obstruction.

Fig. 14 is a photograph of a male subject, aged 62, whose gall-bladder was injected with hot gelatin. On exposing the gall-bladder and ducts, I found the injection had distended the gall-bladder, the cystic and hepatic ducts, but had only filled that portion of the common duct which lies proximal to the bend. In this subject the liver was displaced upwards and outwards so that the fundus of the gall-bladder almost reached the mid-axillary line. This displacement, by pulling on the supra-pancreatic part of the duct, caused kinking and obstruction at the level of the bend,

where a large artery is seen hooking round the duct. The majority of nerve fibres pass to the medial aspect of the duct, and are best avoided by working along its lateral aspect.

Although the mere retention of bile in the gall-bladder is not sufficient to produce gall-stones, still it is one of the most important predisposing factors to their formation.

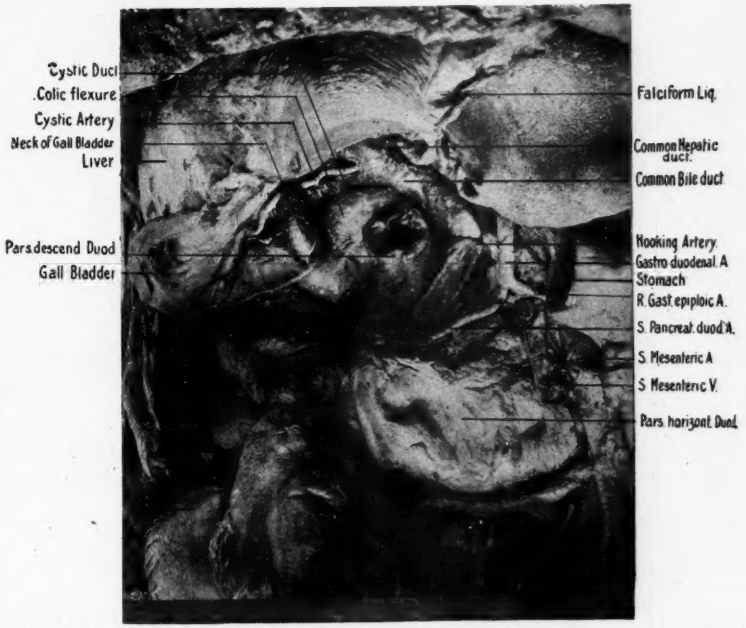


FIG. 14.—Photograph of the gall-bladder, bile-ducts, etc., of a male aged 62. In this subject the following dissection was made:—The anterior abdominal wall was removed and the gall-bladder injected with gelatin, the structures in the gastro-hepatic omentum were then cleaned and the pylorus and pars superior duodeni excised. The common bile-duct, the gastro-duodenal artery and its branches were dissected out, and the head of the pancreas removed. The subject was then placed in the supine position and photographed with a vertical camera

Gall-stones are rare in subjects under thirty, and common in those over fifty. They occur more frequently in women than in men, and of the former they are more frequent in those who have borne children. The common feature in these cases is an increasing tendency to lax abdominal walls, and consequently to enteroptosis. According to Professor Keith (10), gall-stones and enteroptosis are almost invariably concomitant. As has already been explained, the pancreatic division of the common duct is

firmly fixed, while the first and third divisions are readily affected by displacement of the liver and duodenum respectively. These displacements tend to produce kinking of the duct at the level of the bend, thus causing stasis, and creating a condition favourable to microbic activity.

A consideration of the anatomy of the common bile-duct possibly explains the frequent and rapid return of the symptoms of cholelithiasis after cholecystotomy has been performed. As long as the patient remains in bed there is little or no traction of the liver on the common duct, but with the assumption of the upright position displacement and traction may again occur.

It would seem, therefore, that in patients who have had biliary colic, or who have had operations on the gall-bladder, every measure should be taken to improve the tone and power of the abdominal muscles.

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OBSERVATIONS ON CERTAIN STRUCTURAL DETAILS OF THE NECK OF THE FEMUR.

By THOMAS WALMSLEY, M.B., *Demonstrator of Anatomy, Glasgow University.*

THE neck of the femur is a flattened arc of bone connecting the head with the upper extremity of the shaft, passing inwards, upwards, and forwards from the shaft at an angle of individually varying magnitude. The flattening of the neck is from before backwards, and it is narrowest at its middle part, expanding at both extremities, but more so at its outer end where it becomes continuous with the shaft. The vertical diameter of the outer end derives its increase, partly from the manner in which the lower border of the neck passes downwards into the inner border of the shaft (Adams' arch),

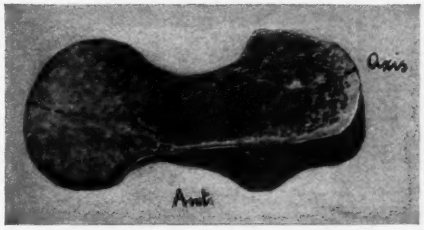

FIG. 1.—Horizontal section of neck and head of femur, showing convexity forwards.

though in addition the whole neck here undergoes an enlargement in all its dimensions. The inner extremity of the neck is more circular in conformity with its attachment to the base of the head, the demarcation being best defined by what is hereinafter termed "the base-line of the head" (*vide post*). Taken as a whole, and as seen on horizontal section (fig. 1), the neck has a slight curvature with the convexity forwards—that is, opposite in direction to the curve which is found at the junction of the base of the neck with the upper end of the shaft.

The anterior surface of the neck extends from the base-line of the head anteriorly to the external limit of the anterior intertrochanteric roughness. For descriptive purposes this surface is here divided into two parts, an outer smooth area, and an inner usually rough area, separated from one another by a hitherto undescribed ridge (figs. 2, 3, and 4). This ridge is

absolutely constant in position in all adult bones, though it varies within wide limits as regards its degree of evidence. In direction it is transverse to the long axis of the neck, parallel to the anterior intertrochanteric line, and distant from that line about 1 to 1·5 cms. It is best marked towards the upper extremity of the neck, beginning, as a rule, abruptly just below the superior border, passes downwards and inwards, with a concavity directed upwards and inwards, and terminates below by gradually fading away into the general contour of the bone about half way down the neck.

FIG. 2.—Proximal extremity of femur, anterior aspect, showing "capsular ridge" in a slight degree of development.

It is thus early to be insisted on that this ridge is not merely the external limit of the medial rough area, but represents the internal boundary of and belongs to the lateral smooth area. The whole evidence of its causation demonstrates this fact. This lateral smooth area is almost comparable to the pulley on the lesser sacro-sciatic notch over which the tendon of the m. obtur. inter. plays at its exit from the pelvis; indeed, in many specimens examined in the recent condition, the whole formation of the superficial structures presents an almost identical appearance. On this smooth area there plays the supero-lateral part of the anterior capsule. In full extension of the limb—the position of greatest tension of its fibres—this part of the

FIG. 3.—More advanced development of "capsular ridge."

FIG. 4.—Well-marked "capsular ridge."

capsule acts in such a spiral manner as to produce this "capsular groove,' concave inwards. A cartilage covering was never noted in this position. An examination of a series of fresh specimens shows how close is the relation between the capsular development and the degree of evidence of the "capsular ridge," and the marking off of the capsular groove. In young bones no such ridge is to be found, nor for that matter is there any indication of an anterior intertrochanteric line. It is about the age of eighteen years that the roughness at the anterior capsular attachment begins to appear; it is progressive in development, yet varies with the amount and strength of the capsular fibres; only subsequent to that period can evidence of the capsular ridge be found, and it is always best marked when the capsule and its attachment are well developed. Bertaux (*L'humérus et le fémur*, Lille, 1891) held that the roughness on the anterior face of the femoral neck was due to partial attachment of the fibrous capsule, a view somewhat similar to that more recently advanced by Frazer ("Some Minor Markings on Bones," *Jour. Anat. and Phys.*, vol. xl. p. 270), who holds that the roughness is due to recurrent fibres from the anterior circular set of capsular fibres. Now, it may be dogmatically insisted on that in the position of this groove there is no recurrence of capsular fibres back on the neck, neither in the fœtus nor at any subsequent period. No matter into how many layers the capsule be split, each layer which has a femoral attachment at all is fixed in the region of the anterior intertrochanteric line, the retinacula being placed in their entirety either proximally or distally to this area. This lateral area, then, devoid of vascular foramina, is a pulley on which there plays the upper and outer part of the anterior capsule, and contact is closest when the limb is in full extension. These facts are made clearly evident if the finger be placed on the groove through a slit in the complete capsule, and the limb slowly extended from the position of flexion.

For the consideration of the significance of the medial area, reference must be made to the articular margin of the head of the femur. This margin is undulating, but in a regular and constant manner as regards the incidence of the causes of the unevenness, though in degree variation does occur to a considerable extent. The undulations are excursions outwards of the articular cartilage, and between these are recessions inwards, or, more correctly, recessions where the excursion of the cartilage over the neck is more limited in extent. The most marked inward concavity is placed opposite the great trochanter towards its posterior part, and bounding this concavity are two outward eminences, one towards the back and one towards the front of the neck of the femur. Of these the posterior is more localised and angular than the anterior, which is more diffuse and rounded, while in size the posterior is much the more constant. This is

proved by the fact that a series of femora may be found, even among European races, in which the anterior of these excursions is continued for some considerable distance over the neck of the femur. This variation was described by Henke (*Handb. d. Anat.*, p. 176), but no special significance was attached to it. Fick (*Handb. d. Anat. u. Mech. d. Gelenke*, Bd. i. S. 318) describes it as the "eminentia articularis colli femoris." Charles ("The Head of the Femur," *Jour. Anat. and Phys.*, vol. xx. p. 1), writing on this same structure from a study of Hindu bones, attributed the condition to an adaptive variation dependent on continuous over-flexion of the joint such as occurs in the "squatting" position. He claimed the condition as essentially Asiatic, and described the European femur as having an even articular margin when looked at from above. Neither of these conclusions can be held as correct; indeed, Parsons ("The English Thigh-Bone," *Jour. Anat. and Phys.*, vol. xlviii. p. 238) has been able to find evidences of marked unevenness in over 60 per cent. of English femora. Poirier and Charpy (*Anat. humaine*, vol. i. p. 220), in discussing this structure, point out that the head is continued down on to the neck anteriorly and posteriorly, while on the anterior face of the neck there is a rough impression, "d'empreinte iliaque," which is occasionally present as a continuation of the articular cartilage of the head. These authors explain the condition as being due to the contact of the neck of the femur with the superior part of the acetabular margin in the position of extreme flexion; but, as Fick has pointed out, considerable abduction combined with internal rotation would also be necessary before this contact could take place, and Parsons' figures emphasise the incongruity of the correlation, when heed is taken of the unnaturalness of the required position.

The medial area of the femoral neck may be found to exist in three different structural conditions, rough in about 70 per cent., almost smooth in about 20 per cent., and in the remaining 10 per cent. more or less cartilage-covered. While the anterior cartilage excursion thus varies to a considerable degree, yet its lateral margin will never be found beyond that definitely marked ridge on the neck of the femur, previously termed the capsular ridge. Now, on closer examination of this excursion in its extreme degree, it is clear that it is not in physiological continuity with the articular surface from which it springs, being curved in one direction only, antero-posteriorly, but perfectly flat in the latero-medial plane. In addition to this fact, I have never been able to find an absolutely smooth surface on one of these extreme excursions. They have never presented themselves in the young subject, and always, in my series, they have been associated with strong bony ligamentous markings, and with powerful capsular bands. Further, in no possible natural position of any of the joints could

this excursion, in any of the specimens in which it was present, be made to enter the acetabular cavity: in other words, when the anterior excursion of the cartilage from the head over the neck is present to an extreme degree, the lateral part of that excursion is never intra-articular in the sense of lying within the acetabulum. It must therefore be concluded that this condition is simply a variation of the more commonly found roughness, which, as already indicated, is placed medial to the capsular ridge. In considering what the cause of this roughness may be, it is

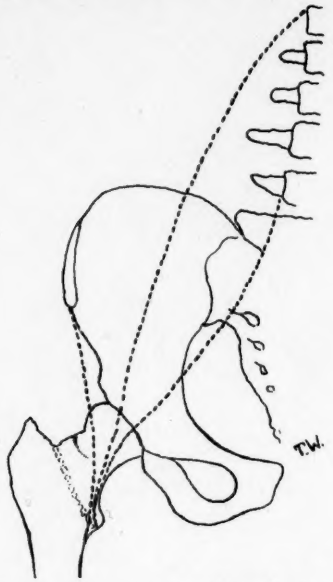

FIG. 5.—To show the usual relationship of the ilio-psoas mass to the proximal extremity of the femur.

necessary first to define the usual relationship of the tendon of the m. ilio-psoas to the proximal extremity of the femur, and especially in the position of full extension (fig. 5). The tendon of the m. psoas is certainly medial to the vertical limb of the ilio-femoral band above, so that when the bursa under that tendon communicates with the cavity of the hip-joint it does so medial to that ligament, and exposes the lateral part of the anterior cartilage of the head of the femur. The iliacus muscle, laterally placed, lies much more on the femoral neck over the vertical limb of the ilio-femoral ligament, and it will be noted that the direction of the concavity of the combined mass is upwards and outwards. Thus

any action which the ilio-psoas may have on the production of markings on the neck of the femur would not only be confined to the lower part of the femoral neck, but there only after acting through a structure more powerful and of greater extent than itself, the medial part of the ilio-femoral ligament. The ilio-psoas, therefore, cannot be made responsible for the marking in question. It is also clear from its extent that this medial rough area, or its variations, does not result from bony contact with the margin of the acetabulum, and the conclusion seems justifiable that the structural condition of this whole area rather represents the amount of contact of this portion of the neck of the femur with the vertical limb of the ilio-femoral ligament in the position of complete extension.

In addition to the two outward eminences already indicated, there was described by Goodsir (*Anat. Memoirs*, vol. ii. p. 508) a third, situated in the inferior shallower concavity at the intersection of the ridge prolonged from the lesser trochanter with the articular margin of the head. In my series, a little anterior to the above-defined position, a very slight outward projection was found in less than 10 per cent. of 200 bones examined on this particular point—a frequency not greater than that of a small outward eminence in the middle of the superior concavity.

Two other markings at the margin of the head of the bone are constant in the series of femora I have examined. First, on the inferior wall of the anterior cartilaginous excursion there is an oval area of fairly smooth, roughly polished bone, abutting against the margin of the head, but belonging to the neck, never cartilage-covered, yet sharply demarcated from the surrounding bone, and differentiated by the absence of vascular foramina. This imprint is undoubtedly produced by bony contact with the margin of the acetabulum. It is intra-synovial in position—that is, the synovial membrane ceases at its lateral border. Contact takes place between this portion of the neck and the articular margin at the anterior part of "the pubic protuberance of the acetabular rim," in the position of complete extension. In this position, extension is combined with a certain degree of internal rotation which takes place primarily to allow the most complete reception of the head of the femur within the acetabulum, and to produce secondarily the locking of the knee-joint. When the femur is thus extended and rotated the anterior excursion of the articular cartilage of the head is in firm contact with the lower part of the iliac area and with the pubic area of the acetabulum, while the imprint described is forced to rest on the latter area at its marginal part. It is therefore proposed that this "facet of rest," or "pressure facet," should be termed the "pubic imprint." In extent the pubic imprint varies a good deal, but

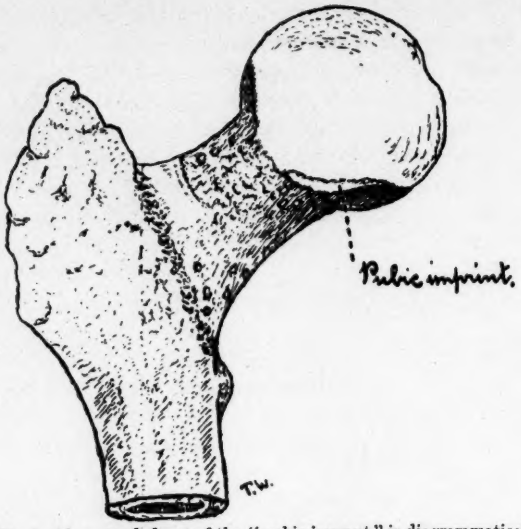

FIG. 6.—The incidence and shape of the "pubic imprint" is diagrammatically shown.

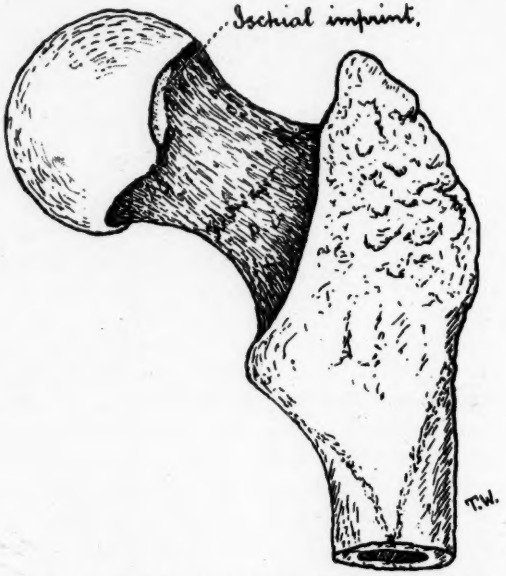

FIG. 7.—To show "ischial imprint"—diagrammatic.

a well-marked bone would show it as about 1·5 cms. long, about ·8 cm. at its broadest part, of oval form but tapering away inferiorly, an incidence in conformity with its incidence of action. At twelve years of age this marking is perfectly distinct, though it is relatively smaller in size than in the adult; but previously to this period it cannot be determined with any degree of accuracy, and is certainly absent up till the sixth year.

Second, the excursion over the posterior part of the neck is, as previously stated, more constant in size than the anterior excursion. It is wholly acetabular in position when the limb is completely extended, occupying in that position the "ischial projection" of the acetabulum. By its upper border it bounds the superior concavity posteriorly, and the bone lying lateral to this boundary corresponds in structure to the pubic imprint. Thus it is proposed to describe another pressure facet on the femoral neck, also constant in position, and, though varying a little in size, of dimensions on the average very comparable to those of the pubic imprint. This facet, differentiated by similar structural characteristics, is produced in like manner to the pubic facet—that is, by contact with the acetabular margin. It is probably differentiated at a later period of life. In respect that the contact takes place with the ischial part of the acetabular rim, the facet may be termed the "ischial imprint."

These two imprints, pubic and ischial, represented in figs. 6 and 7, are most evident in the recent specimen.

THE NECK OF THE FEMUR AS A STATIC PROBLEM.

By THOMAS WALMSLEY, M.B., *Demonstrator of Anatomy, Glasgow University.*

THE angulation of the limbs is a beneficial structural adaptation to the mechanical requirements, and, in connexion with the proximal component of the weight-transmitting couple of which each limb consists, the two points of paramount importance, so far as the preservation of stability is concerned, are the length of the component and its degree of angulation to the distal element.

1. *The Length of the Neck.*—The purposive necessity of the essentially human characteristic of the comparatively great length of the neck of the femur has been assigned to various functional causes, most of which are open to the objection of being simply statements of fact of the existing conditions, and not explanations of those really associated circumstances. For example, it is not necessary to lengthen the femoral neck in order to obtain a greater amount of adductor muscle; rather it should be said that, the neck of the femur being lengthened, a greater amount of adductor muscle will become an absolute necessity. The length of the neck of the femur is really proportional to the breadth of the pelvis.

With the increase of the pelvic transverse diameter in relation to the pelvic antero-posterior diameter,[1] there has been a concomitant increase in the divergence of the lines of weight-propagation from the vertebral column to the lower limbs. For, when the antero-posterior measurements are more carefully analysed, it will be found that the reduction is purely of the post-acetabular part of those measurements; the pre-acetabular, on the other hand, undergoing a relative increase concomitant with the increase of the transverse diameter (figs. 1 and 2). While not seeking to dissociate the final correlation of the causative factor in man from the assumption of the erect position, yet it may be stated that with the increase

[1] Topinard, *Anthropology*, p. 305.

Duckworth, *Anthropology*, p. 295, shows this by means of an index (modified from Topinard), where, when the transverse diameter is 100, the antero-posterior is as follows:—

Edentata	– 138	Lemuroidea	– 144
Rodentia	– 133	Cebidæ	– 135
Carnivora	– 132	Cercopithecidæ	– 134
Ungulata	– 123	Chimpanzee	– 97
		Gorilla	– 79
(Turner, *Chall. Rept.*, xlvii., average of white races):		Homidæ	– 73

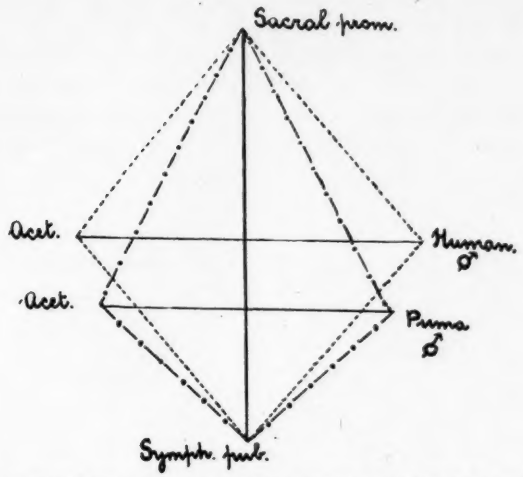

FIG. 1.—The pelvis of a human ♂ has been drawn to a definite scale, and drawn to the same scale the pelvis of a puma ♂ has been super-imposed. Note the amount of divergence of the cotylo-sacral lines depends on the position of the inter-acetabular diameter.

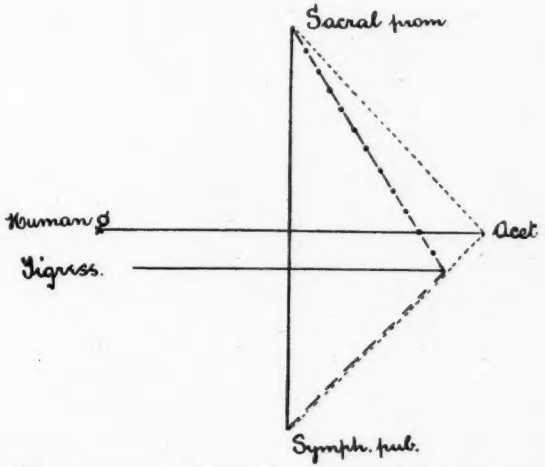

FIG. 2.—Comparison of pelves of human ♀ and tigress, as in fig. 1.

in the transverse towards and greater than the antero-posterior pelvic diameter there is a greater divergence of the lines of weight-propagation from the vertebral column to the acetabula, and on this factor it is proposed that the length of the femoral neck is in direct ratio with the relative distance between the acetabula. In Table I. the measurements carried out and the methods of comparison adopted are fully explained, showing the interrelationship of the various pelvic measurements.

TABLE I.

	Ant.-post.	Post-acet.	Pre-acet.	Trans.	Index.
	cms.	cms.	cms.	cms.	
Ass	14	9·2	4·8	10·4	134
Deer	13·6	9·3	4·3	8·6	158
Sheep	10 1	6·9	3·2	6·7	151
Deer	7·1	5·0	2·1	4·4	161
Tigress	9·7	5·7	4·0	7·2	134
Puma	6·5	4·2	2·3	4·3	151
Cat	3·5	2·2	1·3	2·7	130
Gazelle	6·2	3·9	2·3	4·7	132
Goat	6·2	4·1	2·1	4·2	147
Human (F.)	11·0	5·8	5·2	11·5	95

(Note the apes are excluded from this table.)

Explanation.—The antero-posterior diameter was measured in the usual way; the transverse is taken as the distance between the centre points of the acetabula on the pelvic aspect, which not being the greatest diameter makes the indices given higher than those usually stated. The post-acetabular length is that part of the antero-postular diameter which lies posterior to the transverse measurement, the pre-acetabular that part which lies in front. The pelvic index is calculated as usual.

To refer, though only in passing, to the pelvis as a weight-transmitting structure, it is evident from figs. 1, 2, and 3 what is meant by the relative shortening of the post-acetabular part of the antero-posterior diameter: because, the greater the transverse diameter, the nearer to the posterior boundary of the pelvis is that placed, while a narrow pelvis has that inter-acetabular measurement placed more anteriorly. This is as one would expect, the non-weight-bearing, though strain-resisting, anterior parts of the pelvis depending for their conformation on the weight-transmitting posterior parts.[1] Taking fig. 4 as representing two imaginary pelves, a wide A–B, and a narrow A–C, then owing to the difference of divergence of the weight-transmitting lines, there will be a difference in the inclination to the vertical of the other component of that vertical force of which A–B

[1] For the mechanics of the pelvis reference may be made to Wood's article on the pelvis in Todd's *Encyc. of Anat.*, where, though not stated, the inference here drawn receives full support.

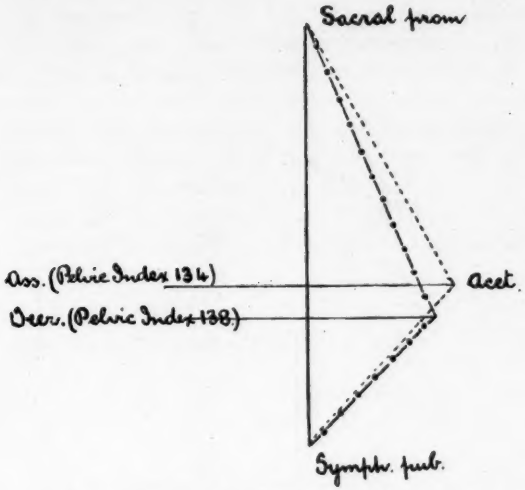

FIG. 3.—Comparison of pelves of ass and deer, as in fig. 1.

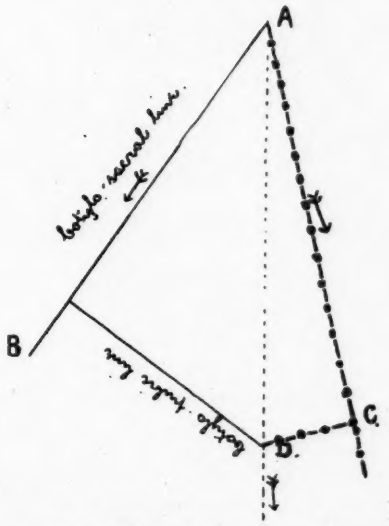

FIG. 4.—To show the effect of the amount of divergence of the weight-transmission lines on the conformation of the anterior parts of the pelvis.

or A–C forms the actual transmission line, and, the more vertical the one component, then the more horizontal will that other component be, but the angle between the two components should, mathematically, remain a constant. Thus a narrow pelvis requires a long post-acetabular as compared with the pre-acetabular part of the antero-posterior diameter; and as the pelvis broadens, the further back will the transverse diameter be placed. In Table II. results on this point are tabulated for the human subject, and fig. 5 is drawn to scale to represent graphically the variations occurring in the adult human subject as regards the pelvic measurements.

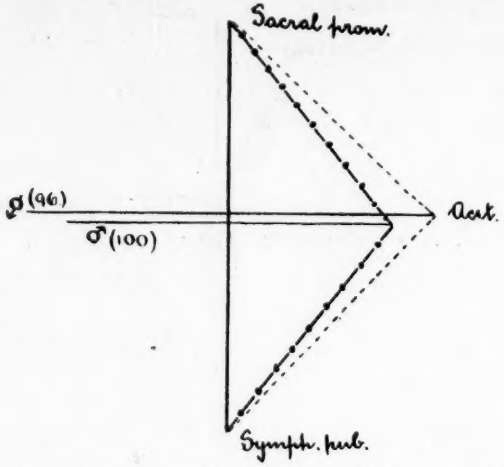

FIG. 5.—Comparison of human ♂ and ♀ pelves, as in fig. 1. The numerals in brackets are the respective pelvic indices.

TABLE II.

	Ant.-post.	Post-acet.	Pre-acet.	Trans.	Index.
	cms.	cms.	cms.	cms.	
Human (M.) . . .	9·6	3·9	5·7	10·7	90
,, ,, . . .	11·8	5·8	6·0	11·7	100
,, ,, . . .	10·3	5·4	4·9	10·8	95
,, ,, . . .	9·9	5·0	4·9	10·4	95
,, (F.) . . .	11·8	5·8	6·0	13·0	91
,, ,, . . .	12·0	6·4	5·6	12·5	96
,, ,, . . .	11·0	5·8	5·2	11·5	95
,, ,, . . .	12·4	6·3	6·1	13·1	94

Explanation.—The various measurements of this table are taken exactly as laid down in the explanation to Table I.

This difference of degree to the horizontal of the pelvic weight-bearing lines of pelves of differing widths will mean a difference in the amount of resolution necessary in order to convert this oblique force into the required vertical from the acetabula to the ground; for, as is shown in fig. 6, the wide pelvis A–A will require a greater amount of conversion of its weight-

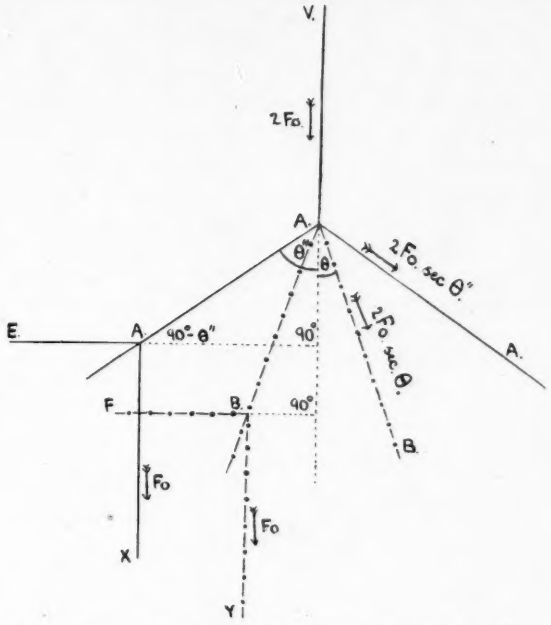

FIG. 6.—To show that the amount of divergence of the pelvic weight-transmitting lines influences the resolution of the oblique pelvic force into the vertical limb force.

Force acting along VA = 2 Fo.
∴ " " " AA = 2 Fo. sec. θ''
" " " AB = 2 Fo. sec. θ.
" " " AE = 2 Fo. tan. θ''
" " " BF = 2 Fo. tan. θ.

But $\theta < \theta'' < 90°$.
∴ $\tan \theta'' > \tan \theta$.

I.e. force acting along AE > force acting along BF.

bearing line A–A into the vertical A–X than will the narrow pelvis A–B into B–Y, always considering, as is here done, that the force acting in the horizontal plane is in all cases approximately relatively a constant. This is still more evident if the two lines A–A and A–B be resolved into their component forces, one of which is vertical, when, as is shown in fig. 6, a

greater amount of pure horizontal force must in the wider pelvis be converted into pure vertical force. On translation of the effects of this factor to the femora, it will in the first place be recognised that, though the sacro-iliac articulation has modified, yet the greater modification rests with the femur. The form of transmission of this oblique into the vertically acting force, which in nature has been adopted in the femur, is from the curved to the

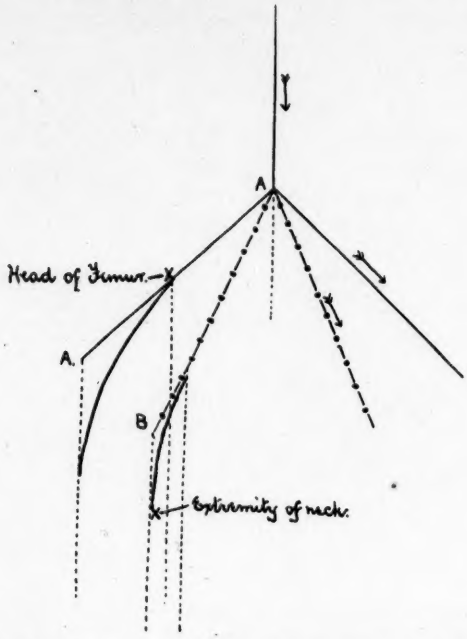

FIG. 7.—The transmission of the oblique pelvic force by means of a curve to the perpendicular. The arcs at A and B are of equal radii.

angular, the curved portion being at the upper end of the bone, with of course the concavity inwards. Now the economic organic tissue reaction is a factor relatively of the same degree throughout the whole animal series; and when this is combined with the simple mechanical fact that in a support of uniform curve and constant strength the greater the approximation of the two opposing forces the longer is the arc required, it will be clear that to compensate the increase of pelvic breadth there must be elongation of the femoral neck. In fig. 7 arcs of the same radius have been made to transmit the oblique force at the femoral head in a curve

from the head to the vertical; and as forces acting along a curve act tangentially to that curve, it is shown graphically that the distance from the femoral head to the point where the force acting tangentially on the curve is purely vertical is in the wider pelvis a longer distance than in the narrow pelvis. Thus, taking the "mechanical axis" of the lower limb—that is, the line of weight-transmission, which, joining the centre of the head with the centre of the knee, passes, when prolonged, through the centre of the ankle-joint—taking this as a vertical constant throughout the whole mammalian series, the greater the divergence of the lines of weight-propagation of the pelvis (that is, the greater the ratio of the pelvic transverse to the post-acetabular part of the antero-posterior measurement), the longer will the neck of the femur require to be.[1] It may be objected that the mechanical axis of the lower limb is not, in the human subject at least, a vertical quantity, but is inclined to the vertical. The amount of this inclination is small, exists only in the uncomfortable military position of "attention" to the extent of 3°,[2] and, inclined as it is to the perpendicular rather than away from it, the result would be not to lessen the length of the neck, but actually to increase it. In Table III. a series of measurements on this point is given, and the methods adopted fully explained.

TABLE III.

	Length of Neck.	Pelvic Trans.	Pelvic Index.	N.-T. Index.
	cms.	cms.		
Tigress . . .	2·6	7·2	134	36
Puma . . .	1·5	4·3	151	37
Human (M.) . .	4·1	11·0	95	37
Human (F.) . .	4·4	12·5	94	36
Deer . . .	3·1	8·6	158	36

Note the constancy within limits of the neck-transverse index of pelves of widely differing pelvic indices. Though the neck has such a definite relation to the pelvic transverse width, the length of the shaft, of course, is not proportional to the length of the neck.

Explanation.—The length of the neck was taken as the distance from the point of intersection of the axes of the shaft and of the neck to the "base-line" of the head, in the axis of the neck. The axis of the shaft is taken as that line which, extending through the centre of the bone, if prolonged downwards would bisect the intercondylar line at the lower end of the femur. The axis of the neck is that line lying in the centre of the neck which bisects, though not at right angles, the "base-line" of the head. This base-line of the head joins the margin of the articular cartilage at the highest point on the neck with the margin at the lowest point, these

[1] Under investigation at the present time by the writer is the question of the reduction of the length of the neck of the human humerus as compared with the neck of lower forms.

[2] Fick, *Handb. d. Anat. u. Mech. d. Gelenke*, Bd. iii., S. 525.

being the two most fixed points obtainable.[1] Tracings of each bone examined were made from the anterior aspect by means of the dioptograph, and the measurements obtained from the projected diagram, which was always of the same dimensions as the original bone. This method was adopted in preference to any other, on account of being the one of smallest possible error, no external measurement being found which was in the least degree accurate. The neck-transverse index (N.-T. index) is calculated thus :—

$$\frac{\text{Length of neck}}{\text{pelvic trans.}} \times 100.$$

Even in the human subject there is evidence of the greater length of the femoral neck of the broader pelvis of the female as compared with the male. Cruveilhier,[2] Hyrtl,[3] and others are all agreed on this point; and though Bertaux[4] found that the neck of the female femur was less than that of the male, and the right neck shorter than the left, yet his absolute accuracy may be doubted, as it is evident from the actual measurements given that some external method of determining the length of the neck was adopted. Sue[5] found the femoral neck "a few lines longer" in the female than in the male. In the present series of bones examined, fifteen male and fifteen female (Table IV.), notwithstanding the relative shortness of the female femur, it was found that the neck was on an average 3 mm. longer than in the male; but individually an enormous variation is present, which variation does not coincide with the length of the femur, nor with the angle between the neck and the shaft.

In tracing the developmental changes in the length of the neck of the femur in the human subject, it is well known that the human fœtus is simian in this respect—that is, the neck relatively to the adult condition is ill developed. On examination of the pelvis at this fœtal stage, though it has been shown by Thomson[6] that sexual characteristics are already present at the fourth month, according to Duckworth[7] the pelvic indices are, for the female 82·4, and for the male 83·6 at this period. Thus, associated with a simian pelvis is a simian femur. There is, however, another factor to be considered as causative. As well as the mechanical force there is another force—a developmental one—found to be a determining factor in the production of the form, length, etc., of the osseous skeleton. But with a normal relationship between the mechanical forces and the

[1] This does not correspond with what is termed by Hoffa the base-line, for his limitation is "that line parallel to the acetabular outlet which passes through the base of the cartilage of the head."

[2] Cruveilhier, *Anat. Descrip.*, tome i. p. 231.

[3] Hyrtl, *Anat. d. Mensch.*, S. 409.

[4] Bertaux, *L'humérus et le fémur* (from Poirier).

[5] Sue, quoted by Humphry, *Human Skeleton*, p. 469.

[6] Thomson, *Jour. Anat. and Phys.*, vol. xxiii. p. 59.

[7] Duckworth, *Anthropology*, p. 296.

TABLE IV.

Measurements of human femur, per dioptograph.

	Length of Femur.	Neck.	Angle.
	cms.	cms.	°
1. F.	38·9	4·5	129
2. M.	42·8	4·2	120
3. M.	40·7	3·3	118
4. F.	43·4	4·9	126
5. M.	45·4	4·2	129
6. F.	44·5	4·3	140
7. M.	45·7	4·3	124
8. F.	45·2	4·7	136
9. M.	44·1	2·9	123
10 M	47·1	4·5	123
11. M.	46·8	3·9	120
12. F.	39·7	4·5	120
13. F.	41·0	4·7	116
14 F.	44·3	4·9	142
15. F	40·0	3·9	128
16. M.	44·7	3·4	126
17. F.	44·5	4·3	137
18. F.	45·3	5·1	130
19. F.	40·7	4·2	119
20. M.	45·6	4·6	122
21. M.	43·7	4·7	126
22. M.	47·6	4·9	135
23. M.	45·6	4·0	132
24. M.	43·8	4·0	137
25. M.	46·7	4·2	113
26. M.	43·2	3·8	123
27. F.	37·6	4·0	124
28. F.	41·4	4·3	125
29. F.	43·9	4·0	122
30. F.	41·1	3·5	120

	cms.
Average length of male femur	44·2
,, ,, female ,,	42·1
Average length of male neck	4·1
,, ,, female ,,	4·4
Average male angle	125°
,, female ,,	127

Explanation.—The length of the neck was obtained as given under Table III., while the angle is taken as between the axis of the neck and the axis of the shaft. The length of the femur is taken as the "mechanical length"—that is, the condyles are placed on a transverse plane and the measurement taken to the head; this, of course, is not the greatest femoral length. Hepburn's osteometric board was used.

developmental forces, the former will serve as a guiding stimulus whereby the latter may most effectively execute the necessary modifications in the different parts of the osseous framework. The converse of this relationship is also true, that whenever there is a disturbance of this relationship there

will be anomaly of form. The disturbance may be in either of two directions, in both cases passing towards complete suppression; for the mechanical may be diminished or suppressed, with the non-control of, or absence of stimulus to, the developmental, a condition leading towards anomalies of form which will be of the embryonic or the primitive type. Or, on the other hand, there may be preponderance, complete or partial, of the mechanical over the developmental, where the anomalies would tend to be progressive, and emphasised at the points of greatest strain. As regards the application of the former to the lower limbs, it would in the adult be found only in such conditions where from abnormal causes the femur has not been required to transmit the weight of the body—for example, in an early complete paralysis, in an early amputation, in extreme hydrocephalus, etc. In the fœtus the developmental force will be in preponderance over the mechanical; that is, the absence of the weight-transmission of the body will connotate an absence of those mechanical factors producing the changes which are so typical in the growing human subject—an increase of the length of the neck of the femur. Thus the absence of the correlation between the mechanical and the developmental forces in the direction of the suppression of the mechanical will in itself constitute a reason as to the shortness of the neck of the fœtal femur. In Table V. there is a tabulation of the measurements of the neck at different ages, showing the relatively great increase once the mechanical strain is brought to bear on the tissues of the neck.

TABLE V.

Age.	Length of Neck.	Length of Femur.	N.-F. Index.
	cms. (av.).	cms. (av.).	
Adult, F.	4·4	42·1	10·2
,, M.	4·1	44·2	9·7
Years, 18 . . .	4·2	44 4	9·6
,, 16 . . .	3·9	40·6	9·6
,, 14 . . .	3·5	37·6	9·2
,, 10 . . .	2·7	34·4	7·8
,, 8 . . .	1 7	25·2	6·7
,, 5 . . .	1·1	17·2	6·4
,, 4 . . .	·9	14·7	6·1
,, 2 . . .	·6	11·6	5·2
At birth, . . .	(·4 ?)	9 4	4·3
Fœtus, 5 months . .	(·2 ?)	4·3	4 6

Explanation.—All the measurements were carried out as before. The neck-femur (N.-F.) index cannot be held as of much value apart from the purposes of comparison. It is taken thus:—

$$\frac{\text{Length of neck}}{\text{Length of femur}} \times 100.$$

It will be noted from the table that there is a steady increase in the relative length of the neck up to the age of 10–14 years, at which period

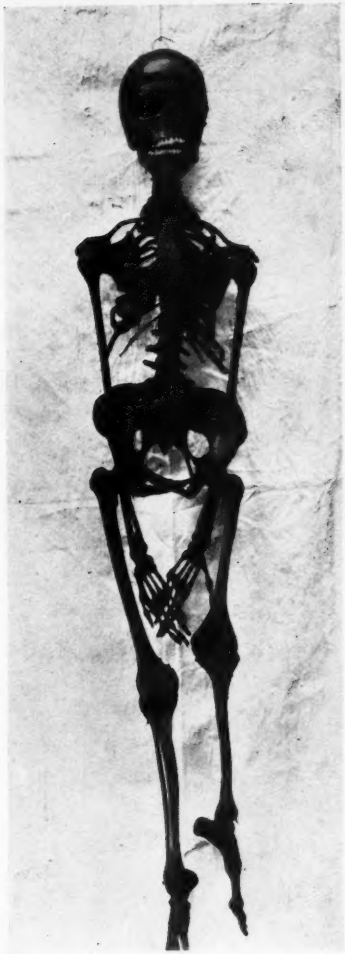

Fig. 8.

the neck of the femur may be said to have reached its maximum ontogenetic length, in the relative sense. Thus it must be evident that, to have any appreciable effect on the length of the neck of the femur in the direction of

non-elongation, the mechanical forces must have been absent from a comparatively early period, though this is presupposing that retrogression cannot take place. I have been able to examine two skeletons in this

FIG. 9.

respect. In skeleton 1 there has been hip-joint disease from an early period, so that the left leg is over all 12 cms. shorter than the right (fig. 8). In comparing the upper ends of the femora, it is more than interesting to note the relatively short neck and the relatively large angle of the diseased

FIG. 10.

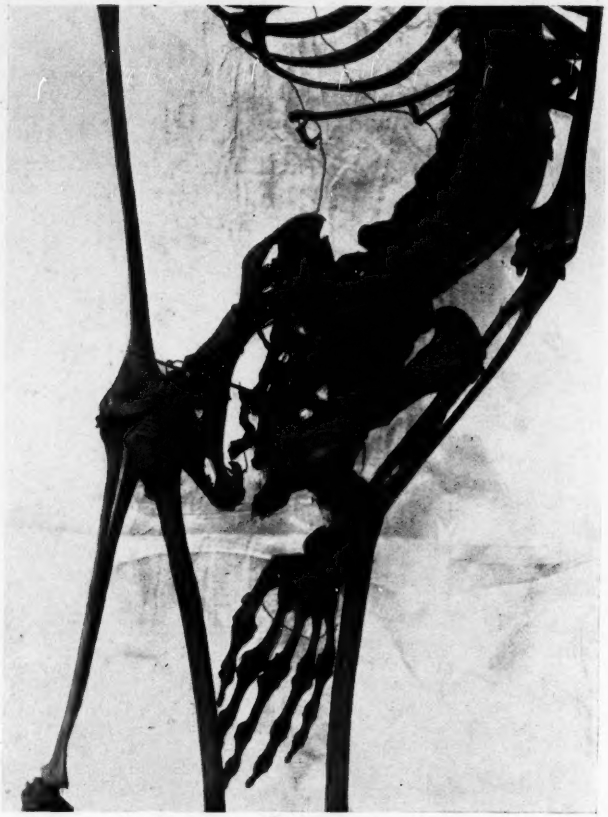

FIG. 11.

side (fig. 9). Absolute measurements were not possible, but those given are at least approximate.

	Length of Femur.	Neck.	Angle.
	cms.	cms.	°
Healthy limb . . .	34·7	3·1	125
Diseased limb . . .	27·5	1·9	140

In skeleton 2 the first glance at the femora is sufficient to indicate that they could not possibly have borne the weight of the body, and here again

the neck of the femur and the angle are of the embryonic type (figs. 10 and 11). The approximate measurements are:—

	Length of Femur.	Neck.	Angle.
	cms.	cms.	
Right limb	33·9	(2·0?)	(140°?)
Left limb	35·1	2·1	135°

The other possibility—that is, where there is a preponderance of the mechanical over the developmental forces—is illustrated in the condition of rachitis. Here, from pathological causes, the developmental forces cannot take their proper place in the production of the form of the bone. Thus, apart from an association with an increase absolute and relative of the

FIG. 12. Rachitic femur. Physiological elongation of the neck.

FIG. 13.—Rachitic femur. Physiological elongation of the neck.

pelvic transverse diameter, the rachitic femur undergoes, concomitant with the increase of its anterior curve, a curving outwards of its upper part, or in other cases a curving inwards of its lower part, more commonly the former. That is, as is shown in figs. 12 and 13, the femoral neck, the curved weight-transmitting line from the head to the vertical, has spread far past its normal limit, and may here be said, physiologically rather

than anatomically of course, to extend from the head past the middle of the shaft.

It may be objected that no account has been taken of another acting force, the muscular force or muscular pull, which by many authors is spoken of as moulding the whole osseous skeleton. Muscular force is, however, a modifying rather than a controlling factor, and will never under normal conditions act in a manner to control or divert the action of the mechanical force. Muscular force is thus simply the dynamic expression of those factors which under normal conditions—that is, with a normally acting mechanical force—temporarily rather than permanently bring about and sustain, in the new direction of the line of force, modifications of the direction of the normal line of action of the mechanical force. Through the continued action in one constant direction, it may be that a local modification in the form, contour, size, etc., will be produced, but never will a normal muscular force control or divert the normal mechanical force. This expression of the influence of muscular force does not in the least detract from what is known as "Wolff's law," wherein it is held "that the shape of the bones is determined by the conditions of reaction to body weight, and the stress and strain of muscular action."

2. *The Angle of the Neck of the Femur.*—The angle of the neck of the femur, often referred to as "the angle of inclination," is here understood as the medially open angle between the axis of the neck and the axis of the shaft. According to the generally accepted yet somewhat diverse statements of different authors, this angle varies throughout the mammalian series, and in man it varies with the age and with the sex. The conclusions of Humphry[1] in regard to this point, those which have become classic, are:—

(1) The angle varies at any given age.
(2) It is smaller in short bones than in long: most likely to be small when the pelvis is wide: the combination of these two usually rendering it smaller in women than in men.
(3) It decreases during the period of growth, but after growth is completed there is no change.
(4) If the limb be relieved of its weight during growth, the angle remains open, or may become wider.

Deductions such as these could not be improved on as bases on which to institute an inquiry into this question—the amount of divergence between the two components of the femur.

In his second conclusion Humphry states that "the angle of the neck of the femur is most likely to be small when the pelvis is wide." From

[1] Humphry, "The Angle of the Neck of the Femur," *Jour. Anat. and Phys.*, vol. xxiii.

this it would of necessity follow that the angle is most likely to be great when the pelvis is narrow. That the angle looks as if it would be smaller in the wider pelvis, one would at a first glance deduce from fig. 7. If, however, these diagrams are read, as they are drawn, in the truly mechanical sense, it will be seen that this cannot possibly be the case, and especially if a resolution is made as in fig. 14. Where, if in the two pelves

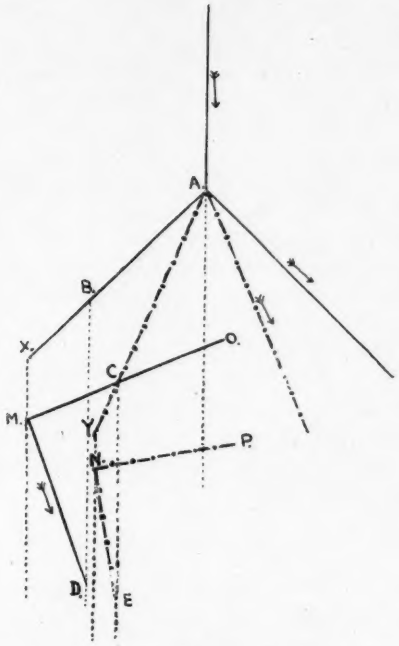

FIG. 14.—To show that the angle of the neck of the femur tends to remain a constant (see text).

A–B and A–C the respective lengths of the necks of the femora be B–X and C–Y, or some lines running between the verticals at B and X and C and Y, with, of course, the neck of greater length in the wider pelvis, then it is obvious that the inclination of the shaft from the extremity of the neck back to the vertical at the knee will always vary according to the length given to the shaft. Now, the deviation from the vertical of the shaft, and in consequence its length, will not be determined by purely mechanical causes, but these will be influenced by other factors, develop-

mental and physiological in the main; yet the less deviation there is, the more economic will be the organisation required, made compatible, of course, with a structure which is convenient for purposes other than mere stability. But the application of the same laws to both pelves, the narrow and the wide, with their respectively short and long femoral necks, will always result in the tendency to a greater proportional length of the femur of the latter pelvis. Now, it is to be noted that this proportional length is not in direct ratio to the length of the neck; for example, in one species if the neck of the femur be twice as long as in a second species, it does not follow that the shaft of the former femur will be twice as long as the shaft of the latter. The connation is only that the shaft of the former will tend to be longer than the shaft of the latter. On this fact rests the reason as to the greater inclination of the femur of the broader pelvis. Now, in fig. 14, if the vertical forces acting along D–B and E–C have as one of their components the femur shafts D–M and E–N in their proportional lengths, then it is correct to state that, though the other components may have a varying direction to the walls of the pelves as expressed by the sacro-acetabular lines, or by the antero-posterior pelvic diameters, yet the angle between the two components will remain a constant. That is, that, *per se*, the width of the pelvis should *not* in the slightest degree influence the amount of divergence between the axis of the neck and the axis of the shaft; what does follow is the difference in the obliquity of the neck of the femur. This tendency to the constancy of the angle of the neck of the femur is borne out in Table VI., where, within limits, the angle remains a constant for the adult.

TABLE VI.

	Pelvic Index.	Angle.	
	(Av.)		
Human (F.) . . .	94	127°	
,, (M.) . . .	95	123	
Gorilla	147	120	(Duckworth gives 124°).
Tigress	134	123	
Ass	134	127	
Deer	158	125	
Puma	151	128	

Explanation.—All these measurements have been detailed before. Fig. 15 shows how various measurements are taken.

(*N.B.*—It is a significant fact that the angle which the morphological neck of the humerus makes with the shaft of the bone is in the human subject 125°–130°.)

In application of this constancy to the adult human subject, Humphry's first conclusion, "that the angle varies at any given age," is only too evident. In Humphry's series there was a range of degree from 113° to 136°, other writers, as a rule, admitting a similar variation. It is obvious that this

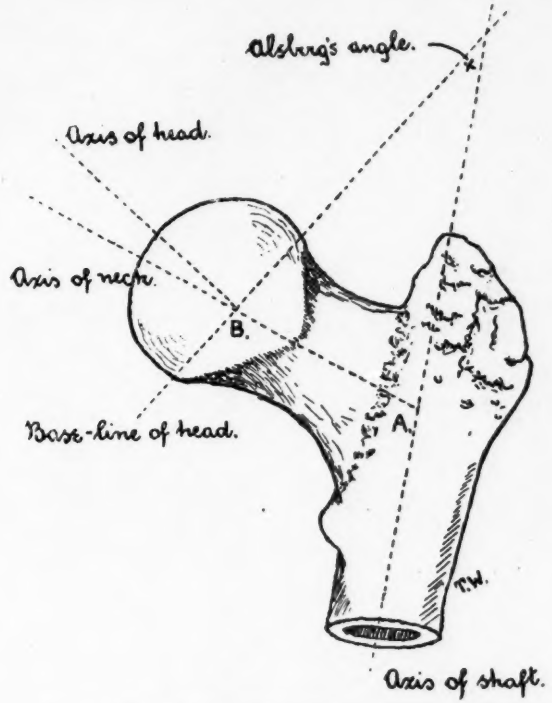

FIG. 15.—To show how various measurements are obtained.

Angle at A is angle of neck of femur; A–B is length of neck of femur.

variation is purely individual, and is of much greater extent than that found between the average of man and other mammals. Individually there is variation in the breadth of the pelvis (Table II.), in the length of the neck, and in the length of the shaft (Table IV.), but these variations can in no possible manner be correlated to the variations of the angle.[1] The

[1] Hirsch (*Anat. Hefte*, Bd. xxxvii.) puts forward the view that a long neck is associated with a large angle. The same author (*op. cit.*, 1899, S. 10) correlates the angle and the area of the transverse section of the shaft.

causes must be assigned to differences in individual developmental reaction, causes which can never lend themselves to proof.

Now, as regards the sexual variations which are said to exist in respect to this angle, Humphry has summed up the accepted view in his conclusion, "that in short bones the angle tends to be small, and it is most likely to be small when the pelvis is wide." Both of these statements, even in their limited application to the human subject, are founded on the idea that the femur will be developmentally plastic, but the inclination of the neck to the horizontal has been considered as remaining absolutely fixed. That is, that the one factor which can be shown to vary Humphry has concluded to be unchangeable, and if this hypothesis were correct the angle would be smaller in the shorter femur of the female. But in view of what has already been proved, and in light of the results given in Table IV., the angle can in no sense be said to vary directly with the sex. In his work on this angle, Luschka[1] formulated the conclusion that the female angle was actually greater than that of the male; Hyrtl[2] describes the angle as being the same in both sexes; Charpy,[3] in his measurements at all ages and in both sexes, came to these conclusions: "The angle in the young person is greater than in the adult; in the adult it is the same for both sexes, on an average 127°; in the old person the angle is the same as for the adult." Parsons,[4] in a recent series of measurements of 300 bones, found the male angle as 126·5° and the female as 125·5°, and states as his conclusion, "that the angle of the neck is of no value as an indication of sex."

In the study of the ontogenetic changes of this angle there is universal proof that the divergence is greater in young children than in the adult, and greater in the fœtus than in the child. This change in the angle of the growing bone—a decrease in degree concomitant with the increase in age—is dependent on the controlling influence of the mechanical over the developmental forces. By pure development the whole neck tends to be more or less directly vertical, or perhaps spiral; thus the open angle in the fœtus, thus the open angle of the femur on which strain has never been put, *e.g.* Humphry's measurements in early amputations, paralysis, etc. Reference may also be made to skeletons 1 and 2 already described. On to this vertically directed neck there is transmitted through the head of the femur a shearing force, acting vertically, which is tending to produce an angle between the two components through which that vertical force is transmitted, and as a result of this there will be, not a bending of the osseous or cartilaginous tissues of the neck of the femur, but a difference

[1] Luschka, *Anat. d. Mensch.*, Bd. iii. S. 339.
[2] Hyrtl, *Anat.*, S. 409.
[3] Charpy, *Bull. de la Soc. d'Anthrop.* (Lyon), 1884.
[4] Parsons, "The English Thigh-bone," *Jour. Anat. and Phys.*, vol. xlviii. p. 260.

in the plane of the epiphyseal cartilage of the head. This epiphysis is horizontally placed in the fœtal bone, and to assume the adult oblique position, there is, as it were, a greater amount of growth at the outer end than at the inner end of the plate.[1] (This point will be more fully dealt with later.)

Many authors also hold that there is a senile change—a further reduction of the adult angle. Against this change Humphry has written most conclusively, and on a series of measurements of senile bones bases the deduction "that there is no tendency for the angle to collapse in old people." In other words, the mechanical and the developmental forces having acted up till the end of development in producing a structure best suited for the individual organism, there is, normally, no tendency for that structure to change. Substantiating Humphry's dictum, there is the conclusion of Charpy, "in the old person the angle is the same as in the adult." Ward,[2] writing on this supposed senile characteristic, says, "This change (the decrease of the senile angle) is not so constant as Cloquet[3] and other anatomists would seem to represent them: for on examining the thigh-bones of very old subjects in the dissecting-room, I have found many entirely free from the described peculiarities, and indistinguishable, in respect to form, from the femur of the well-formed adult." Bell,[4] who first drew attention to the processes of interstitial absorption upon which these progressive metamorphoses depend, describes it not as a healthy action natural to the senile period of life, but rather as an abnormal process incident to a debilitated or otherwise morbid condition of the economy in particular individuals.

[1] There are authors who hold to the idea that the main factor in the reduction of the angle is the pull of the ilio-psoas muscle. It can only be at the most of minor importance, as is evident from those cases of amputation below the insertion of the muscle, where the angle is still found large (for cases, see Tubby, *Orthop. Surg.*, vol. i. p. 629).

[2] Ward, *Osteology*, p. 263.

[3] Cloquet, *Hum. Anat.* (1828), p. 142. (*N.B.*—This is not Cloquet the anatomist, as Ward leads one to believe, but H. Cloquet, Professor of Physics at Paris.)

[4] Bell, Benj., F R.C S. (Edin.), *Interstitial Absorption of the Neck of the Femur*, 1824.

(1) TWO CASES OF CERVICAL RIBS. (2) AN ANOMALOUS ARRANGEMENT OF THE VAGI.

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Two Cases of Cervical Ribs.

In the study of these two cases of cervical ribs, particular attention has been paid to the other costal and vertebral elements, and also to the constitution of the cervical, brachial, and lumbo-sacral plexuses.

Subject 1, female. presented bilateral cervical ribs; the left was 6 cm. long, and did not quite articulate with the 1st thoracic rib, but was attached to its medial border by a short band of fibrous tissue. On its upper surface were two grooves, the anterior very well marked and evidently produced by the lowest trunk of the brachial plexus, the posterior more shallow, formed and occupied by the middle trunk.

External and internal intercostal muscles were present, and also a well-marked scalenus minimus, arising from the tip of the cervical rib, and spreading out over the upper surface of the 1st thoracic rib. The subclavian artery just crossed the origin of this muscle, and thus lay below the lowest trunk of the plexus and on a more anterior plane (fig. 1).

The brachial plexus on this side received some fibres from the 4th cervical root directly, and also indirectly from the fibres of C 4 to the phrenic nerve. The 1st thoracic nerve sent a small branch to the normal 1st intercostal space, and also to the space between the cervical and 1st thoracic rib, before joining the 8th cervical nerve (see fig. 2).

On the right side the cervical rib was less well developed, measuring only $2\frac{3}{4}$ cm. Its upper surface presented a groove for the middle trunk of the brachial plexus. The tip of the rib gave origin to a similar muscle to that described on the opposite side.

No communication was found between the 4th and 5th cervical nerve roots. The 1st thoracic nerve gave off branches to the normal 1st space and also to the highest, but the root of the 1st thoracic nerve joining C 8 was appreciably larger on this side than the other (see fig. 2).

The lumbar plexus was normal on both sides. The vertebral and other costal elements were also normal. The 12th thoracic ribs were fairly

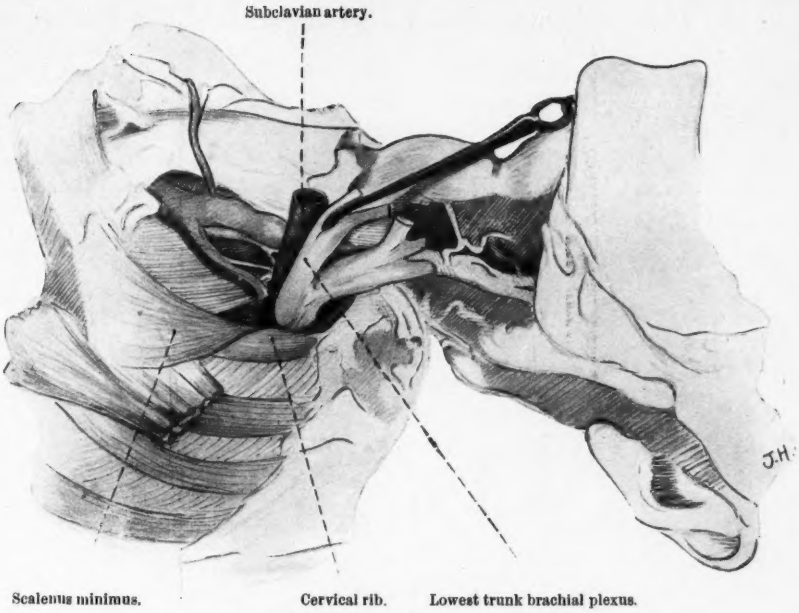

FIG. 1.—Dissection showing relations left cervical rib.

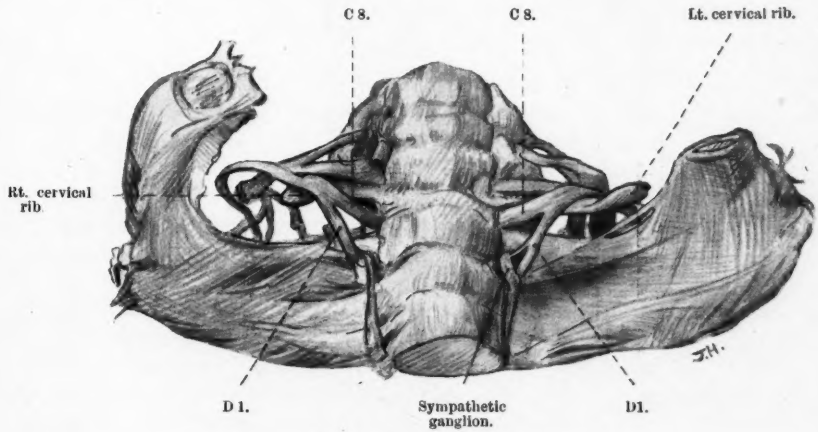

FIG. 2.—Course of 1st thoracic nerve.

well developed, and measured 10 cm. on the right side and 10½ cm. on the left.

Subject 2, male, also presented bilateral cervical ribs, each 4¼ cm. long, and their upper surfaces were grooved by the middle trunk of the brachial plexus. External intercostal muscles arose from their outer borders, and scalenus minimus from their tips. The antero-medial fibres of these muscles formed a free edge over which passed the lowest trunk of

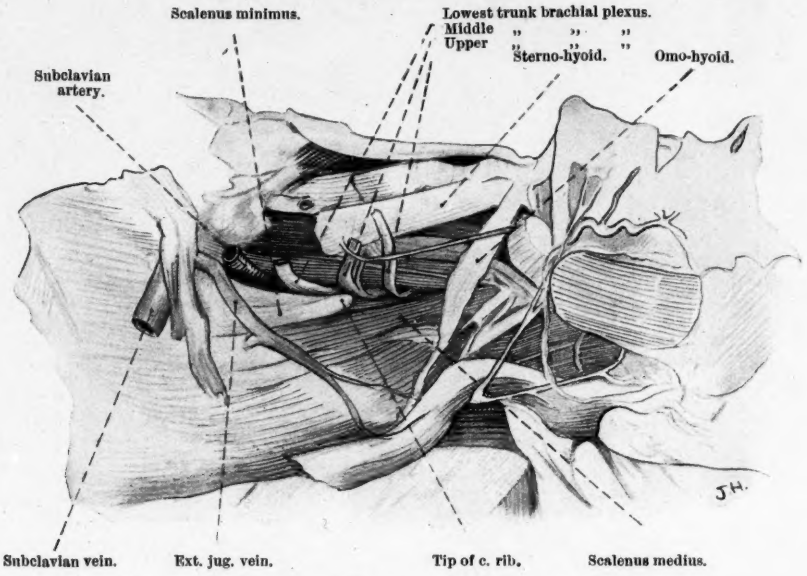

FIG. 3 (Subject 2).—Dissection showing relations left cervical rib.

the brachial plexus and the subclavian artery (see fig. 3). Internal intercostal muscles were also present. The brachial plexus was normal, and the 1st thoracic nerve of either side, after furnishing a small twig to the normal 1st space, joined C 8 below the tip of the cervical rib by a short wide trunk (see fig. 4).

The lumbar plexus showed a certain amount of prefixation (see fig. 5). On the right side, the obturator and anterior crural nerves received very few fibres from L 4, the bulk of the fibres going to form the lumbo-sacral cord; on the left side, more than half the fibres of the root joined the 5th L nerve, but the condition was not so marked as on the right. The ilio-hypogastric came from the last dorsal nerve, and the external cutaneous

came from L 1 and 2 on the left and L 2 only on the right. This prefixation of the lumbar plexus was associated with absence of the 12th thoracic ribs. The right and left transverse processes of the 12th thoracic vertebra measured 2·5 and 3 cm. respectively, and presented the appearance of normal 1st lumbar transverse processes. The 11th thoracic ribs were each 16 cm. long. Five lumbar vertebræ were present. The sacrum consisted of six pieces, having apparently assimilated a caudal element.

The 1st thoracic ribs of this subject presented no subclavian groove. The nerves of the brachial plexus and the subclavian arteries were kept

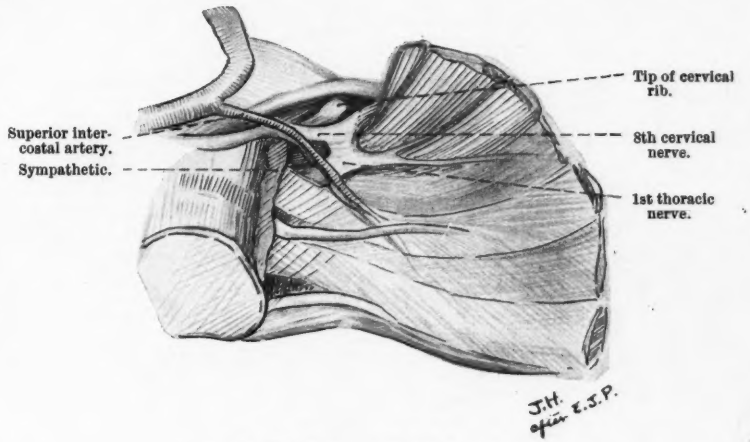

Fig. 4 (Subject 2).—Left side from below.

off from the rib by scalenus minimus muscles (see fig. 3). These latter muscles and the external intercostals produced a well-marked groove on the superior surfaces of these ribs; the groove running parallel with the inner borders of the rib, and extending as far forward as the attachment of scalenus anticus.

The points of interest in these dissections are the following:—

(1) In subject 1 the larger cervical rib is associated with a prefixed brachial plexus, the latter not only receiving fibres from C 4 root, but also receiving fewer fibres from T 1 than the plexus does on the opposite side, where the rib is less well developed.

(2) In subject 2, absence of the 12th thoracic ribs is associated with a cephalic movement of the lumbo-sacral plexuses.

These facts are in favour of there being a causal association between

the formation of limb plexuses and the development of costal elements. Further, from the study of these and other cases it seems probable that, as has already been suggested, (1) prefixation of the brachial plexus leads to the production of cervical ribs, and post-fixation to a deformed or abortive 1st rib; and also that prefixation of the lumbo-sacral plexus causes small or absent 12th thoracic ribs, and post-fixation in varying degrees leads to production of 1st lumbar ribs with corresponding degrees of development.

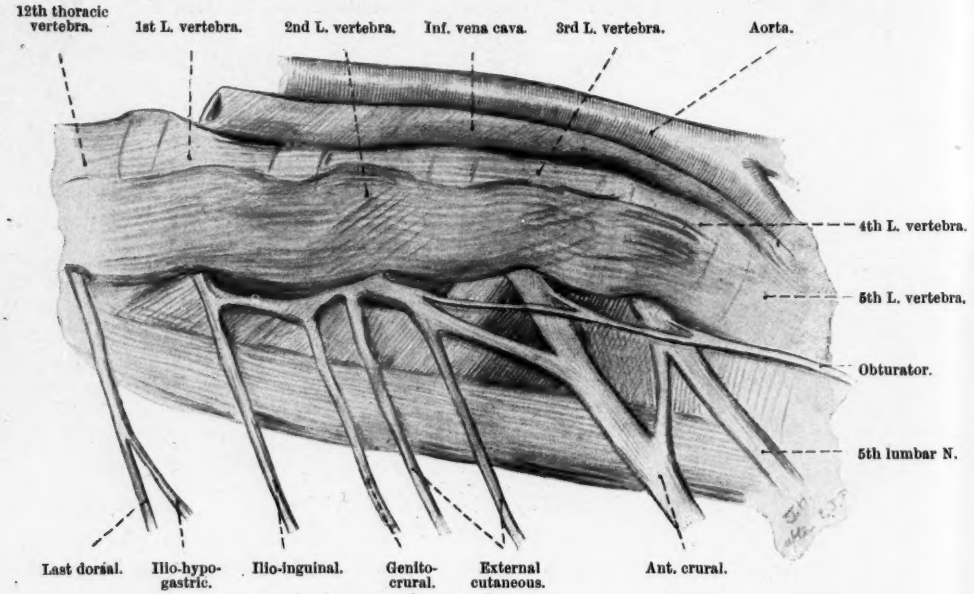

FIG. 5 (Subject 2).—Lumbar plexus.

The fact that the sacrum has assimilated a caudal element is anomalous, for the movement of the sacral elements is not usually opposed to the movement of the lumbo-sacral plexus.

With regard to the clinical aspect, it is conceivable that the conditions present in the first subject may have caused some symptoms, but in subject 2 the lowest trunk of the brachial plexus did not pass over the cervical rib on either side. No evidence of physical signs, referable to the rib condition, was found in either case, and no information as to symptoms could be obtained from notes on the cases, as both were mental.

I am greatly indebted to Miss Hardy and Miss Partridge for their drawings of the dissections.

REFERENCE.

(1) Wood Jones, F., *Jour. Anat. and Phys.*, vol. xliv., "On the Relation of the Limb Plexuses to the Ribs and Vertebral Column."

An Anomalous Arrangement of the Vagi.

The photograph illustrates a very unusual arrangement of the vagi. The left nerve enters the abdomen behind the œsophagus, and the right anterior to the gut. The œsophageal plexus was formed by branches given off from both nerves.

Anomalous vagi.

Normally, the vagi dispose themselves in one of two ways when they emerge from the posterior pulmonary plexus:—

(1) Two large branches issue from the pulmonary plexus on either side, apply themselves to the sides of the œsophagus, and break up at once into an inextricable network of fibres which surrounds the gut. From this plexus two nerve trunks emerge, and the left passes anteriorly and the right posteriorly into the abdomen. This is the appearance usually described, but the following arrangement is equally common:—

(2) One trunk (or two which speedily unite) emerges from the pulmonary plexus on either side: the left takes up an anterior and the right a posterior position in reference to the gut. The plexus gulæ is then formed by numerous branches uniting the main trunks.

Wertheimer (1) found that these anastomoses presented a relatively constant arrangement. A large branch from the left nerve passed behind the œsophagus and joined the right nerve just above the diaphragm, and also less constantly a smaller branch passed from the right vagus to join the left vagus in front of the gut. It is generally accepted that the normal position of the vagi at the lower end of the œsophagus is due to the rotation of the stomach. The anomalous arrangement of the vagi in this specimen appears, at first glance, to be at variance with this theory; but the explanation suggested is, that the greater part of the fibres of the right and left vagi respectively run in these cross branches described by Wertheimer, so that after rotation of the stomach the main part of the fibres of the right nerve lie anterior and the main part of the left vagal fibres lie posterior to the gut.

It is therefore submitted that this arrangement of the vagi is only the result of a gross exaggeration of a fairly common condition, and is not incompatible with the theory of rotation of the stomach.

REFERENCE.

(1) *Compt. rend. Soc. Biol.*, 1901, p. 832.

ANATOMICAL NOTES.

THE INTERNAL MAMMARY ARTERY ARISING FROM THE THYROID AXIS. By Professor FAWCETT, *University of Bristol.*

THIS case, recorded by Professor Fawcett, is apparently a rare one. The artery arose some distance above the origin of the thyroid axis from the subclavian of the left side, and descended into the thorax in front of the left phrenic nerve. It gave off

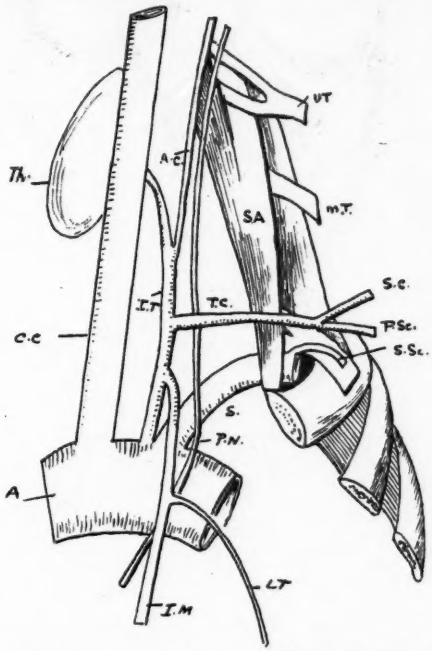

FIG. 1.—Internal mammary artery arising from the thyroid axis artery.

A., aorta; C.C., common carotid; A.C., ascending cervical artery; I.M., internal mammary; I.T., inf. thyroid; M.T., middle trunk brachial plexus; P.N., phrenic nerve; L.T., lateral thoracic branch of internal mammary; P.Sc., posterior scapular; S., subclavian artery; S.Sc., infrascapularis; U.T., upper trunk.

a large lateral thoracic branch on the medial aspect of the ribs. The suprascapular artery arose from the third part of the subclavian artery, and the constituent parts of the upper trunk of the brachial plexus perforated the scalenus anticus muscle.

PROFESSOR FAWCETT showed a specimen (the second he had seen) in which the EXTERNAL SEMILUNAR CARTILAGE was modified as in the illustration. It is a condition which apparently is comparatively rare, for Lick in Bardeleben's *Anatomy*

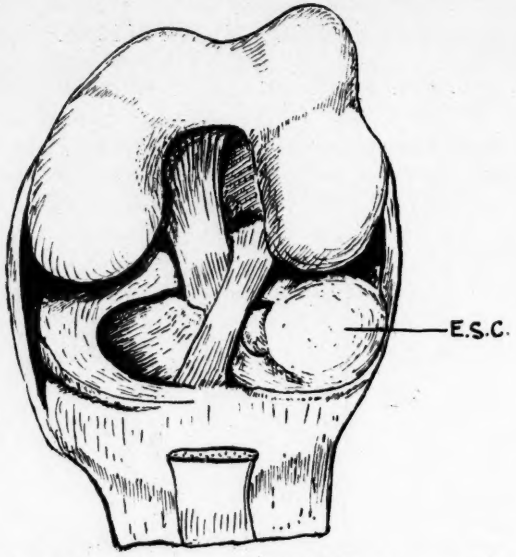

FIG. 2.—Drawing of left knee-joint opened from the front, to show complete circular, disc-like, external semilunar cartilage (E.S.C.).

records having seen one in which a foramen existed the size of a pea, and two cases are mentioned by Poirier, *Traité d'Anatomie*.

Professor Shaw states that Bruce Clarke saw three such cases in one limb.

In the specimen illustrated a strong posterior accessory band tied the hinder horn of the cartilage to the posterior aspect of the posterior crucial ligament.